New England Water Works Association

ORGANIZED 1882.

Vol. XXXVI. March, 1922. No. 1.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

MAKING CHLORINE AT THE POINT OF CONSUMPTION.

BY CLARENCE W. MARSH. *

[*Read September 15, 1921, at Bridgeport, Conn.*]

The modern idea is to save time. Use electric power at the point of consumption and make your product. This saves time and money. Ask the housewife who has a home with applied electricity as a servant, or the superintendent of any factory with the latest electric appliances to save labor. There is something real in the smoothness and continuity of operation in the midst of clean surroundings which always accompanies the use of electric power. It attracts the best class of labor. It reduces effort and makes labor attractive and interesting.

Finished manufactured products usually require additional work and equipment to handle, control, and prepare these products for use at the point of consumption. Attendance is required on these devices and machines for the final preparation of these products. A great deal of unnecessary work can be eliminated if the product can be made economically at the consumer's plant. It saves time, labor, equipment, and materials, and therefore real money. This is the basis for your consideration of making chlorine by the consumer.

The growing demands for sterilizing and purifying reagents for water and sewage has caused a great expansion of the use of chlorine, the cheapest and most efficient medium. Its commercial forms are bleach, or chloride of lime, and liquid chlorine. In the first case, lime acts as the carrier of the chlorine and the bleach is shipped in expensive steel drums which are non-returnable. In the second case, the chlorine gas is compressed and liquified by refrigeration and the liquid chlorine is shipped in steel cylinders under high pressure, and these cylinders must be returned to the manufacturer.

Why not make the chlorine gas on the job? This is the best and most efficient way, because the chlorine is made as a gas under atmospheric pressure or less, and is immediately available for use and in exact proportion to the dosage and water pumped, without the need of further control apparatus.

* Consulting Engineer, New York.

Why is it not done to a much greater extent? Up to the present time there has not been enough recognition of the basic economy of producing chlorine as wanted at the point of consumption without the necessity of tying up money in inventories, in shipments, and at the factories. There is not enough knowledge of various steps in the manufacture and distribution of chlorine in the possession of the consumer. Manufacturers of bleach and chlorine have shown very commendable zeal in the sale of their products, and have helped the consumer by placing in his hands excellent devices for the control and dosage of chlorine to water. There has not appeared an efficient enough machine at reasonable cost in the market until recently, to make chlorine in small quantities for the small consumer. These machines usually are too big in size and involve considerable expense for space and maintenance.

Recently there has been developed an electrolytic cell battery which takes very little space and is a unit, not several units, which means few parts and a very low cost of repairs, renewals, and depreciation. In addition to this the efficiency with which power is used makes the cost of production of chlorine 20 per cent. less than present methods and cuts the waste of materials used in cells to less than one half that which formerly seemed necessary. It places a more efficient machine in the hands of the small consumer than the largest manufacturers of chlorine use to-day. Heavy investments in expensive equipment which has not been depreciated and amortized prevents manufacturers acting promptly in adopting more efficient machinery, because it means accepting a heavy loss now when he can least afford it.

Let us analyze the fundamental reasons why it is cheaper to manufacture chlorine at the point of consumption rather than at a distant point. It challenges the older methods of manufacture and distribution under modern conveniences and conditions with electric power at reasonable rates available to every community in the land and the necessity to eliminate every possible expense, such as transportation, the many steps to put the product in the form required for transportation and then re-transforming to the desired form used by the consumer, and many overhead expenses accompanying these unnecessary steps, including the manufacturer's profit.

The consumer will use four times as much bleach as chlorine. Bleach contains 35 per cent. available chlorine when it leaves the factory, but only 25 per cent. or less can be counted upon because of deterioration in storage and the losses of chlorine in making solutions of chloride of lime. We will use this figure in making comparisons. Present market prices will be used. The prices are approximately 50 per cent. above pre-war prices for bleach, and approximately the same as pre-war prices for liquid chlorine. Ultimately all prices will probably be equal to pre-war prices.

What is the cost of materials at the point of consumption for bleach, liquid chlorine, and chlorine made at the point of consumption?

Bleach costs $42 a ton at the factory. Freight averages $4 per ton, and cartage to the point of consumption about $2, or a total for transportation of $6. Containers are included in the price and must be disposed of by the consumer. The cost for the equivalent of a ton of chlorine is 4 × $48 = $192.

Liquid chlorine costs $160 a ton at the factory for the small consumer, and probably more unless under contract. Freight or, rather, express, because of the small number of cylinders and the necessity of keeping small quantities on hand owing to the hazard and the capital tied up in inventories, will cost at least at the rate of $0.80 per 100 lb. weight. There is 100 lb. of container for every 100 lb. of chlorine, and this additional 100 lb. must be returned by freight or express.

Then 3 × $0.80 (including cartage if by freight) = $2.40 per 100 lb. chlorine, or $48 per ton. Containers will call for an investment of $500 for the average-size consumer, which is in the form of a deposit to cover the value of the cylinders, and probably the wear and tear on the cylinders will devolve on the consumer. Call it "interest and depreciation" on $500 at 30 per cent. for a consumption of 50 lb. chlorine daily. $\$\frac{150}{9} = \$16$ per ton of chlorine. The total cost per ton of chlorine is $224.

The production of chlorine at the point of consumption with Marsh cells calls for the following materials and power:

Salt used equals 4 lb. per 1 lb. of chlorine, 4 tons at $5 = $20 per ton of chlorine. Freight carloads lots, $4 per ton and cartage $2 per ton. Total for salt = $44. This considers that the caustic soda liquor is either sold or thrown away. If the salt in the liquor is recovered, then the cost will be $22 per ton of chlorine.

Graphite, diaphragms, and depreciation of all other materials in the electrolytic equipment will cost, including the labor entering into these materials, $10 per ton of chlorine. The freight or express is included. The amounts are very small.

Power will be based on an average rate of 2c. kw.-hr. A difference of 1c. kw.-hr. above or below this will affect the cost by $25 per ton. The power used per pound of chlorine is at the rate of $1\frac{1}{4}$ kw.-hr. per pound (2 500 kw.-hr.) per ton. At 2c. per kw.-hr. cost = $50 per ton of chlorine. The total cost for all materials will be $104, or $82 per ton, depending on whether the salt is recovered from the caustic liquor or not.

What is the cost of labor and attendance? In all cases material must be handled by labor, and the equipment necessary must receive some attention and must be frequently inspected. The use of bleach, liquid chlorine, and the making of chlorine is no exception.

Bleach comes in steel drums weighing about 800 lb. each. These drums are stored away until ready to use. Chloride of lime solutions for application to water are made by mixing the bleach with water and allowed to settle for clear solutions before being used. This solution is then ready to be fed by some control device in proper proportions and at the rate re-

quired by the pumping rate of water. Labor and equipment is required for handling these solutions. On account of the dust and smell, the space required must be partitioned off from other building space, or separate buildings used. This makes it less convenient to superintend the operations and increases the cost of attendance if the control apparatus is located in the same space as the mixing.

Liquid chlorine comes in 100-lb. steel cylinders which contain 100 lb. of chlorine. A certain number of these cylinders is kept in storage, ready for connecting up to the control apparatus. Shipments of cylinders are made frequently, and considerable labor is involved in handling the cylinders and in connecting and disconnecting them. On account of the hazard of storing high-pressure chlorine, separate buildings are recommended, thus removing dangerous conditions to firemen in case of fire. This means extra cost for buildings and attendance, but the precautions against unnecessary risks are unavoidable. Control apparatus does not last, and frequent replacements of expensive parts must be made if the apparatus is to function properly and leaks be avoided.

Chlorine gas is made by electrolyzing brine solutions. Direct current of electricity is passed through these solutions in containers which support the electrodes. Acheson graphite is used as the anode or the positive pole, and steel plates which are perforated for the negative pole. A diaphragm of asbestos cloth or paper is placed between the electrodes, and is usually supported by the negative plate or cathode. The chlorine gas is collected in the top of the container holding the brine and is taken away under a slightly reduced pressure through a water ejector, and distributed to the water to be sterilized. The mixture of caustic soda and salt solution which percolates through the diaphragm is collected in containers outside of the cell proper. Hydrogen is also evolved at the cathode and may be collected or wasted in the air. One or more cells are used, and this battery, which is a unit, is placed in one box or container or pit with partitions between the cells. Fifty lb. chlorine requires a pit or box $2\frac{1}{3}$ ft. by $2\frac{2}{3}$ ft. inside; 300 lb. chlorine daily, $4\frac{2}{3}$ ft. by 5 ft.; 1 000 lb. chlorine, $4\frac{2}{3}$ ft. by 15 ft. 8 in.; $1\frac{1}{4}$ kw.-hr. per 1 lb. chlorine is required. If power is 2c. or under, and it is desirable to keep the apparatus very small, then with a rate of $1\frac{2}{3}$ kw.-hr. per 1 lb. chlorine the apparatus can be reduced to ONE-HALF these sizes. This indicates the small space required. The cells can be placed in any laboratory, and moved around in the battery box wherever wanted, or can be permanently located in the floor. In an operating position the battery will be about 12 in. high above the floor line. If placed in a box, the battery will be 3 ft. high.

An assurance of the very best care and inspection is guaranteed when an apparatus is located in a laboratory or in the same room with other machinery which must be inspected and with a mimimum cost for attendance. The tops of the cells are tight, and the gas is evolved at a reduced pressure and withdrawn as fast as made and ejected to the water to be

sterilized through water ejectors. As soon as the current is turned off the production of chlorine ceases. Chlorine is made in proportion to the dosage required and according to the rate of water pumped by changing the amount of current automatically. Chlorine is produced proportionally to the electric current flowing through the electrolytic battery.

Electric rectifiers consisting of small vacuum bulbs such as mercury bulb rectifiers used in charging automobile storage batteries are being perfected to transform the electric current to direct current at a high efficiency of transformation. These rectifiers offer simplicity and a minimum attendance for the smaller capacity plants. Small motor generator sets with spare machines will take care of the larger capacity outfits. These electrical devices or machines are standard, and, as all know, are very reliable converters demanding very little attention.

Where electric current is generated at the plant it can be generated as direct current, thus saving the loss of transformation. In some cases steam is used for pumping, and then electric current can be produced very cheaply through the use of small steam-turbine-generator units.

The salt may be stored in a dry form on the floor or in bins, or, better, under brine in outside wood or concrete tanks, when brine will always be available. This brine is mixed with a little soda ash and caustic liquor from the cells, to settle out calcium and magnesia salts. It is done in batches in small wood or concrete tanks located inside the building, and if of concrete made a part of the building. The brine is made neutral by adding small amounts of acid, and is ready to feed to the battery through a level control box and automatic floats in the cells.

We must judge the costs of attendance by the convenience of inspection and the continuity and reliability of the respective methods. In general it may be assumed equal in all cases. Mechanical devices can be made very reliable. Electrical machinery had advantages which are not denied. Users of each type seem to be satisfied as regards these features.

For small plants the item of attendance is very important, and in the case of producing chlorine, using liquid chlorine or bleach, even the minimum attendance amounts to as much as all the other costs put together. Where regular attendance is insisted upon or furnished, then it is by far the largest item of costs. In the larger plants this item of attendance is relatively a smaller cost.

It would seem that an electrical appartus for the smaller plants would find considerable favor on account of the smaller cost of production for materials and the convenience of having the apparatus placed in a laboratory or in the same room with other apparatus, insuring a maximum attention at a minimum cost and without hazard and obnoxious conditions.

Interest and depreciation is an item of expense which must be considered in each case. The life of an apparatus varies under differing conditions, and estimates of this item of cost will vary. Nevertheless,

equipment must be constantly renewed, and it is essential that it be well taken care of and that the parts are inexpensive.

Control apparatus for bleach solutions are usually crude devices and subject to rapid deterioration and need a great deal of attention to prevent irregularity of feed due to the nature of the corrosive liquid and deposits of lime, etc. The control apparatus, however, is usually made up of comparatively inexpensive parts, which probably makes this apparatus the cheapest to maintain. For a 50-lb. chlorine daily feed for interest and depreciation the expense per ton of chlorine would be approximately $500 at 50 per cent. $\$\frac{250}{9}$ tons = $28 per ton of chlorine made available.

For liquid chlorine very satisfactory control apparatus has been designed. The parts, however, are made of expensive metals and they are subject to very severe conditions. The high cost of machinists' labor and the necessity to make renewals of costly silver fittings makes the charges for deterioration fairly expensive. Some estimates vary from two years' to five years' life. Apparatus must be installed in duplicate for this reason, which makes it more costly. For a 50-lb. plant approximately $1 000 at 33 per cent. interest and depreciation would mean $\$\frac{330}{9}$ = $36 per ton of chlorine.

For producing chlorine we have already allowed for the materials and depreciation of all parts, including labor on the battery. The brine storage tanks, as in the case of bleach liquor tanks, are a part of the building and may be charged to building. There remains the depreciation on the electrical transforming apparatus which is standard and reliable, electrical machinery having a long life, and parts can be replaced at minimum cost. We have the interest on the investment of the battery to consider, however.

Interest on $1 000 at 6 per cent. for battery for 50-lb. chlorine daily	$60
Interest and depreciation, $1 000 at 12 per cent. for transforming apparatus for above	$120
Interest and depreciation, $200 at 12 per cent. for all other equipment except battery	$24

Total, $\frac{204}{9}$ = $22 per ton of chlorine produced.

Charges for interest and depreciation on buildings and storage equipments may be considered about the same, but of course if separate buildings are required in the cases where hazardous and obnoxious conditions exist, then this extra cost should be considered as against the factor of convenience and small expense entailed when the apparatus can be accommodated in a laboratory or in a room with other equipment at relatively low cost.

Overhead expenses for the purchase of materials, payment of labor, shipments of materials and containers, and the financial settlements and cost of money tied up in inventories are all factors.

Bleach would probably be shipped in less than carload lots approximately once a month. Liquid chlorine would be shipped by express twice a month. Salt would be shipped in carload lots in bulk twice in three years. The frequency of shipment may be considered as a gage of the

relative expense for these three methods, and can be assumed to be $20 per ton for liquid chlorine, $14 per ton of chlorine for bleach, and $3 for the salt where chlorine is made at the point of consumption.

A credit should be allowed in the case of making chlorine when the caustic soda liquor can be used in the vicinity. It can be used in industrial centers and communities by soap concerns, laundries, and others, in the form made or by further concentration and evaporation, when the salt will be recovered and credited to the chlorine as stated. One and one-seventh pound of caustic soda is made for every pound of chlorine. The market price at present is 4c. a pound. It seems as though at least one half of this price could be obtained for the liquid caustic soda solutions. One and one-seventh lb. x 2c. $= 2\frac{2}{7}$c. per pound of chlorine, or $45.70 per ton of chlorine, to be credited.

It is apparent that from a financial standpoint there is an advantage in making chlorine at the point of consumption, and that from ONE-HALF to THREE-QUARTERS of the cost can be saved yearly. For larger plants this will be increased many fold.

A description of THE MARSH ELECTROLYTIC CELL BATTERIES, which has been referred to in the above comparisons of cost for the manufacture of chlorine at the point of consumption to the cost of using bleach or liquid chlorine for the sterilizing or purification of water and sewage, may be interesting and appropriate.

We will take, for example, the average small installation of a battery to make 50 lb. of chlorine daily. The best type for this size will be an intermediate size known as " Type 6-EC-2." Three cells in a battery will be required, but a fourth cell will be supplied for a spare. An entire duplication of apparatus is not required, as the spare unit will replace any of the others when it is necessary to renew the diaphragms once in six months to one year. The anodes once in two years or longer.

Each of these cells will produce 17 lb. of chlorine daily at a rate of approximately $1\frac{1}{16}$ kw.-hr. (D. C.) per lb. of chlorine or $1\frac{1}{4}$ kw.-hr. (A. C.) after transformation of current per pound of chlorine at the switchboard. The current used will be 260 amperes at 2.8 volts per cell, or 8.4 volts at the cells for the battery of 3 cells. This is for a period of six months. The cells are approximately $2\frac{1}{2}$ ft. long by 10 in. wide by $2\frac{1}{2}$ ft. high. In an operating position, i.e., when lowered in a box or pit, the cell is less than 12 in. above the top to the box or floor line.

If electric current is reasonable, these cells can be operated to produce 34 lb. daily per cell at a rate of $1\frac{1}{3}$ kw.-hr. (D. C.) per pound of chlorine or $1\frac{2}{3}$ kw.-hr. (A. C.). The current used will be approximately 520 amperes at 3.6 volts. This is an average for four months' operation.

If a movable battery is wanted, the cells are placed in a battery box fitted with castors. If it is not to be moved, then the cells are placed in a pit in the floor. This pit, to accomodate three cells operating and one spare,

will be 2½ ft. wide by 5 ft. long by 2 ft. deep. The inside dimensions of the box will be the same.

The cells consist of three parts. The concrete top, which may be suspended from above and to which is attached perforated and horizontally corrugated steel plates carrying in turn several sheets of asbestos paper conforming in shape to the steel plates. The steel plates are the cathodes and the asbestos paper is the diaphragm. The anodes, of Acheson graphite, are suspended from the top and are enclosed by the steel plates which form the compartment for receiving the brine solution or electrolyte. With a few fittings such as the copper conductors, the automatic brine feed floats, the gage glasses for determining the height of the brine in the cell, and the chlorine outlet from the top of the cell, the cell is complete. The top is solid except for the openings for the anode, float and the chlorine outlet, which are sealed tight against leakage of gas.

Are there any expensive parts to the cell? No.

The top is a concrete casting of small dimensions, and will last five years or longer. It is subject to no stress because it is not restrained in any direction. It can be readily replaced at very small cost.

The cathodes are sheets of corrugated steel which last not less than five years. They are inexpensive.

The anodes are the most expensive but weigh only about 85 lb. for the above type. They last two years without replacement. The material is of the cheapest form. Cylinders 1¾ in. to 2 in. diameter and 2 ft. long, and a post rectangular in shape and approximately 2½ ft. long, all pinned together with graphite pins.

The fittings are glass, rubber, and lead; all standard commercial forms and cheap.

There are no expensive metals or other materials involved. The machinist's work is limited to the work of pinning the graphite together, and this is furnished to the user at a minumum cost, due to the special machine tools which does the work quickly and cheaply because of the quantity production.

Discussion.

Mr. Frank W. Green. * I might say, as one of the operators of a plant where we generate our chlorine in this way, that although we have a very poor cell, and this cell of Mr. Marsh's seems to be a very great improvement upon our cell, we reported to the State Board of Health the cost of 1½c. for home-made chlorine and 8½c. for liquid chlorine purchased on contract. But that does not include the cost of the electric current. Most of the time we are running on water power, and figure the current does not cost us anything, and therefore we do not lay a charge for that. I

* Superintendent of Filtration, Montclair, N. J., Water Company.

think Mr. Marsh's figures are very conservative. That is to say, there would probably be more of a saving with a cell of that sort over liquid chlorine than he claims; for instance, our salt costs less than $10 a ton delivered.

I know of any number of men who have had to go to the hospitals due to chlorine poisoning on account of the valves of liquid chlorine tanks getting away from them. Now they have a better valve than formerly, and there may not be quite as much danger. But where you have a substance like chlorine under a high pressure there is always some danger, and men are apt to be careless after they get familiar with a thing of that sort, and we always have more or less potential danger.

Of course, in the case of generating it at the point of application, the chlorine is always under a slight suction. Then on the dosage; — where an electro-chemical engineer makes chlorine he figures entirely from an electrical standpoint; but I might say for the benefit of the chemists, that as the chlorine is absorbed by water, going in to the supply as a solution of chlorine, the amount of chlorine can be very readily checked up by taking the volume and the strength of the solution. In this way one gets a chemical check and it works out very nicely.

I know of four water plants that manufacture their chlorine at the present time, and all of them, so far as I know, are very well satisfied. They all continue to make it and find a saving in every way. At Trenton the cells are in a room with the rest of their apparatus, and there is no odor, no dirt, nor any other objectionable feature. I think that at most of the plants the cells and apparatus are examined every hour, but every well-managed plant would do that when using liquid chlorine. There should be an inspection of any apparatus of that sort at least once an hour, no matter how automatic it is supposed to be.

Another point: I noticed that with these tall brine tanks, as shown, Mr. Marsh says it is possible to settle out all the impurities. I think that the four plants in operation all filter their brine. They find it is quicker, and we are used to filtering, so that we just filter.

Another feature for the small plants which it might be well to bring out is that in all the cells that exist at present — I mean, the former cells — they insist on continuous service. I do not know how Mr. Marsh's cell is in that respect, and I think it is quite important if you can discontinue and use at will.

With the old cell — we use a Nelson cell — our greatest difficulty is graphite sludge forming in the bottom and stopping the circulation. Also in the " sulphating " of the connections between the bus bar and the individual rods that go to the several square carbons.

I have asked our foreman a number of times if he would rather manufacture chlorine or use liquid chlorine, and which he thought was the better, and he is very strongly in favor of our generating our own chlorine. He likes it much better than the use of liquid chlorine.

MR. MARSH. All cells are alike if you treat them right. The main essential is to purify your brine and filter or settle it. Ordinarily, water-works engineers know what to do when they want to settle out stuff. Filtering is a thing the chemist is versed in.

MR. GREEN. The brine filter is a very crude apparatus. Just run it through about a foot of sand. We find there is considerable dirt in the salt.

MR. MARSH. A better thing would be a plate filter, or filter press. That is what they use in the large chlorine plants.

In regard to the continuity of service, there is one thing I want to point out. In the large manufacturing plants they have a certain amount of equipment that they want to keep busy all the time. They have a certain number of cells, and in order to make money you have to keep your equipment running at normal capacity. If it runs under or above, it is poor manufacturing. On the other hand, to produce chlorine as you want it, this cell has been made for that purpose. It has such a low voltage that you can vary your current within wide limits and get your chlorine in the amount wanted. In our case it does not make so much difference, because you can't control the amount of liquid chlorine within 5 per cent. anyway, so that you are well within the limit if you produce 5 per cent. excess. Our position in water works is entirely different from a big manufacturing plant.

What was the other question?

MR. GREEN. In the continuity of service you mentioned, the number of water plants that run only twelve to fifteen hours a day.

MR. MARSH. It is undesirable to shut down the cells. I mean, it would be much better to absorb the chlorine in lime water and keep the cell running. But as a rule I have found in water-works service, you want to vary the amount of dosage, and keep a continuous flow. If you want 3 lb. of chlorine, you turn your ampere meter corresponding to 3 lb. Your efficiency varies a little bit, but within 5 per cent.

In regard to the sulphating at the connection, there are ways to overcome this which I will be glad to show you. Almost every big plant has a different method, and it is merely a matter of conforming to certain well-known facts. There is no secrecy about it.

MR. WELLINGTON DONALDSON.* May I ask Mr. Green how he charges up his power? He gets a surprisingly low figure.

MR. GREEN. Well, I did not consider power, because it is all generated by water power.

MR. DONALDSON. That is, you did charge it in the cost of a cent and a half a pound?

MR. GREEN. Oh, no. The electricity costs 2c. to 4c. a pound.

MR. MARSH. The power cost on these cells with direct current will vary from 1 kw.-hr. per pound of chlorine up. If you want to double the rate of chlorine you go up to $1\frac{1}{3}$ or $1\frac{1}{2}$ kw.-hr., direct current.

* Sanitary Engineer, American Water Works and Electric Company, New York.

You multiply your kilowatt-hour rate by 1, 1⅓ or 1½, plus the conversion cost from A.C. to D.C. But, as I say, approximately 1¼ kw.-hr. times your kilowatt-hour rate would be the cost per pound of chlorine at normal capacity.

MR. E. S. CHASE.* This paper of Mr. Marsh's is very interesting and recalls various earlier attempts to produce chlorine by electrolytic methods for use at the point of disinfection. If I recall correctly, there were at least two instances in New York State where electrolytic chlorine was used; one at Brewster, N. Y., for sewage disinfection, and another at Utica, N. Y., for water disinfection.

In connection with the estimated cost of chlorination by means of hypochlorite installations and with liquid chlorine apparatus, it would seem desirable to secure actual costs from plants in operation. The compilation of such costs would be well worth while.

In Mr. Marsh's estimate he figures the depreciation of the chlorine cylinders as a part of the cost upon the consumer, but it is my understanding that such depreciation falls upon the manufacturers of the chlorine rather than directly upon their customers.

Properly designed bleach plants, for example one at New Rochelle, N. Y., have not been found particularly difficult or inconvenient to operate. In fact, it does not appear on the face of it that apparatus for the control and application of chlorine solution prepared from chlorine generated at the water-works plant would be any less difficult to handle and control than bleach solution as ordinarily prepared.

Relative to handling liquid chlorine cylinders, the labor is comparatively small. Furthermore, the space required for storage of considerable quantities of chlorine in liquid form is not large, as contrasted with the storage required for salt bought in carload lots, from which chlorine would be generated electrically.

It would appear to me that the apparatus for applying the chlorine solution made with chlorine produced electrolytically would not be materially simpler than the ordinary solution tanks and constant level orifice boxes used with bleach apparatus. Furthermore, were movable electrolytic cells used it would seem that the problem of conveying the gas to the point of application would be somewhat complicated.

While there is no question that such apparatus could be properly cared for, as Mr. Marsh suggests, in the laboratory or where machinery is located which must be inspected, this same advantage holds true with liquid chlorine apparatus. On the other hand, many chlorination plants are located in isolated spots where inspection is relatively infrequent.

The automatic electrical control of the production of chlorine appears to offer some advantages, but just how this would be applied is not clear from Mr. Marsh's paper, — presumably from the use of a Venturi meter on the water main. A question which I would like to ask Mr. Marsh is

* Sanitary Engineer, with Metcalf & Eddy, Boston.

whether the evolution of chlorine from the brine takes place at the same rate with a freshly charged cell as with a cell containing brine from which the chlorine has largely been liberated, assuming the same amount of electricity passing through the cell?

In connection with the electrolytic cell it must be noted that continuous electric current is apparently essential. Consequently, on services where interruptions are liable to occur there would appear to be considerable opportunity for interruption in the chlorination process and danger of untreated water being delivered to the municipality.

Another question which arises is as to how the ordinary attendant available at a water-works plant, not employing a chemist, would know when his electrolytic cell would have to be provided with fresh brine. Is there not, therefore, the possible danger of the brine having its available chlorine exhausted without the water-works operator being aware of the condition?

On the whole, it would appear that the electrolytic production of chlorine for the disinfection of water and sewage might well prove advantageous in the case of the larger installations where the quantities of water or sewage to be treated are large, where adequate storage facilities are provided and proper expert supervision maintained. It would appear to the writer that in case of the majority of the smaller water works where chlorination is the sole method of purification, the complications of the process would render it decidedly difficult to utilize with any assurance of proper disinfection of the water.

MR. MARSH. Chlorine gas is withdrawn from the electrolytic cell batteries under suction by a water ejector and delivered to the main body of water direct.

There is no apparatus needed for the control and application of a chlorine solution other than a water ejector.

A water ejector is all that is needed to apply the chlorine to the water.

The chlorine is made proportionately to the electric current passing through the cells. The electric current is controlled by hand or automatically.

The chlorine is therefore delivered to the ejector and the water without the need of such things as solution tanks, etc.

The chlorinated water from the ejector passes through a rubber hose to the point of application, in the same manner as practiced in using chlorine gas from liquid chlorine.

Either apparatus can be located in a laboratory or in a separate building. It is only a question of hazard under unusual conditions such as leaks or fire.

Chlorine stored under high pressure is more hazardous than chlorine generated under suction and which requires no storage of chlorine. Throwing an electric switch will stop the electric current and stop making chlorine. This is a simple and effective procedure.

Both methods need occasional inspection wherever located.

Chlorine is constantly generated at a fixed rate when the amperes or electric current is fixed. The difference in a new and old cell is about 5 per cent. This is allowed for by slightly increasing the amperes in an old cell.

The brine is constantly fed to the cell, and there is no difference in the quality or amount of brine in a new or old cell.

If electric current is interrupted, sodium hypochlorite can be made from the chlorine and caustic soda liquor from the cell and held as a solution for emergencies. This solution can be applied to the water through the water ejector during the interruption of electric current.

Or steam generated or oil and gasoline generated electric-power apparatus can be held in reserve for emergencies instead of reserve transformer apparatus.

Or liquid chlorine and bleach can be held in reserve.

Fresh brine is being constantly fed to the cell and held at a predetermined level by feed floats. A chemist is not needed. The attendant simply observes if the brine level is all right.

The electrolytic generation of chlorine is like other things not yet in universal use. Oftentimes we imagine a thing is complicated if we know little about it. General use removes this error.

POLLUTION OF STREAMS AFFECTING INDUSTRIAL USES.

BY J. FREDERICK JACKSON.*

[*Read September 16, 1921.*]

The uses of water in a manufacturing state like Connecticut are varied, but in general divide into two broad classes, — potable and industrial. The classes merge in some cases where plants use the municipal supply for both drinking and manufacturing. The effect of stream pollution on either is of considerable importance. Plants using large volumes of water in the processes of manufacturing take most of it from rivers where its quality is satisfactory. Where it is not, they are forced either to use the city supply, to obtain water from underground sources, or seek a distant supply on some unpolluted stream. Some plants for economic reasons prefer to take river water as it is and treat it for use in their particular process. The additional expense thus entailed is often a considerable item in fixing the price of the manufactured article.

In general, once a stream becomes grossly polluted by domestic or industrial wastes, it is eliminated as a source of potable supply. No attempt is made in this state to use grossly polluted rivers for drinking purposes, so that stream pollution as affecting this use of water can be disregarded in this discussion. Exceptions are the use in cases of emergency, such as that of the Connecticut River by Hartford in the drought of 1900 and where dual connections are permitted for fire protection. The cost of treatment in the one, and constant and close supervision in the other, required to protect public health, makes the pollution in these cases serious. Even if the rivers were clean, under present conditions they would be used for these purposes only in an emergency.

INDUSTRIES USING WATER.

The industries using the largest volumes of water are the copper and brass, iron and steel, the rubber, the textile, paper and the silk. It is difficult to state the volume used in each trade, because in many plants no record is kept and estimates vary widely. On some streams the entire flow of a river is diverted through the plant at certain seasons of the year. Some idea may be had from the following estimates of the volume of water used by all industries on the Naugatuck and Hockanum rivers:

WASTE WATERS FROM FACTORIES.

	Gal. per Day.
Naugatuck River	73 082 000
Hockanum River	8 000 000

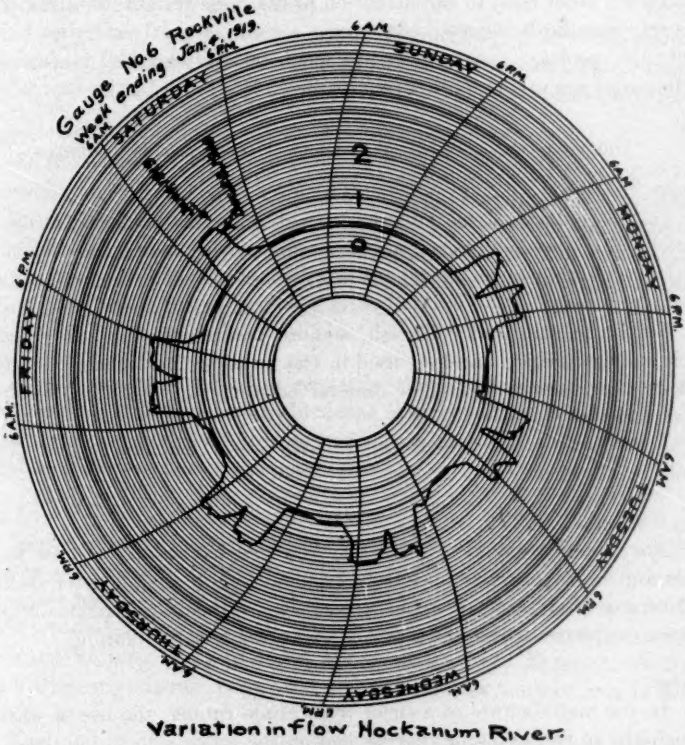
* Director, Bureau of Sanitary Engineering, Connecticut Department of Health.

WATER CONSUMPTION.

	Gal. per Day.
Naugatuck River	21 050 000
Hockanum River	1 740 000

The relation between the use for domestic and industrial purposes is shown clearly by these figures, and even more so if we consider two specific cases.

The estimated water consumption of Torrington is 2 710 000 gal. per day. The plant of the Coe Brass Company in this city used from its own private supply 8 150 000 gal. per day.



Variation in Flow Hockanum River.

The estimated water consumption for Waterbury is 11 600 000 gal. per day. The Scovill Manufacturing Company from its private supply used 13 950 000 gal. per day.

In this connection the record of gage heights of the Hockanum River below the city of Rockville is very interesting.

By comparing flow for week days and Sundays, it appears that twelve factories use practically the entire flow of the river in their processes of manufacture.

Evidently, then, one of the main considerations determining the location of industries on our rivers was volume of flow. The constancy of this volume is another very important factor, but we do not propose to discuss that here.

The second main consideration affecting the use of water industrially is quality.

The quality of water desirable for boiler purposes has been the subject of much discussion, and the amount and character of chemical constituents permissible have been quite definitely determined. Obviously it is of much importance in industrial use, but it is unnecessary to discuss it in detail here, other than to call attention to the undesirability of attempting to apply standards determined for one section of the country to others where the geology, topography, and physical and chemical constituents of the water are markedly different.

Use and Quality of Water in Different Industries.

Copper and Brass.

In this industry large volumes of water are used in separating the particles of copper and brass from the dirt and other mineral matter in the ash from melting furnaces, for cooling the rolls, and in the pickling and rinsing processes.

Sulphuric acid and soda ash, sodium bichromate, sodium cyanide, nitric and hydrochloric acid are used in the pickling and rinsing operation, and any excessive amounts of mineral constituents would undoubtedly affect these.

If free acid were present in the river water, machinery and piping would be attacked.

Iron and Steel.

The use of water in this industry is somewhat similar to that in the brass and in cleansing articles from rust and oil, in rinsing after pickling and rinsing after plating. Soda and caustic soda are used in the cleaning process, sulphuric acid in the pickling, and cyanide in the plating.

Rubber.

In the manufacture of articles from crude rubber, the use of water is principally in the softening process and on the rolls.

In the regeneration of rubber large volumes of water are used in the process of devulcanization. Some sulphuric and hydrochloric acid are used and a considerable amount of alkali.

The industries in the Naugatuck Valley are for the most part more concerned with the effect of the river water on the efficiency and life of their boilers than its effect on manufactured articles. In general, they feel that any water that would be suitable for steaming purposes in a power

plant would be satisfactory for general industrial use. It is recognized, however, that pollution by decayed animal or vegetable matter, acids and excessive amounts of lime and magnesia are undesirable, and in any cleansing operation, freedom from color, odor, suspended matter, microscopic organisms, and fecal bacteria is desirable.

Woolen Industry.

The use of water in this industry is for scouring and rinsing the raw wool, dyeing, carbonizing and fulling. Soda ash and soap are used in the scouring, various dyes in the dyeing, sulphuric acid in the carbonizing, and soda ash in the fulling and milling.

A water free from suspended matter, free acid and peaty acids and iron, not too high in color and with limiting amounts of calcium, magnesia, sulphates and chlorides and organic matter, even though non-fecal, is required.

Paper.

In the paper industry large volumes of water are used in boiling of rags, in washing the rag and paper pulp, in bleaching, in cooling rolls of machines, in the moistening process and in the presses. A water similar to that required in the woolen industry is necessary, though in the manufacture of strawboard or rougher grades of paper the limiting amounts may be much greater than where finer grades are made.

Bleaching and Dyeing.

Bleaching and dyeing are generally closely associated with woolen, paper and silk industries; and where this is so, constituents affecting color or hardness and polluting organic matter are detrimental, and iron, even in traces, is very serious in the dye baths.

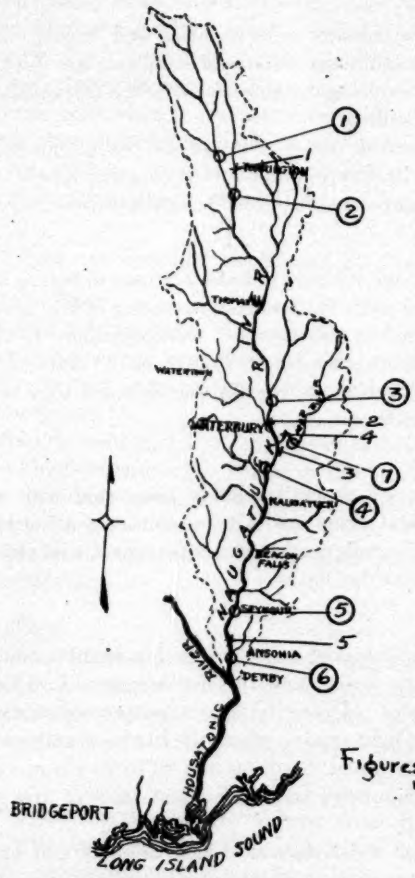
Silk.

In this industry large volumes of water are used in washing and boiling cocoons and frissons, in the sizing, and the dye houses. Two principal factors are hardness and color. Except for special purposes such as boiling off the silk and dyeing very light shades, where the hardness and color must be reduced to zero, 15 to 30 p.p.m. hardness and 10 to 25 p.p.m. color are permissible, any organic impurities and the faintest trace of iron is detrimental.

The quality of a water is determined by the amount and nature of polluting materials it may contain. These substances are those naturally inherent in the water, which it has taken by contact and holds in a dissolved or suspended state, and the added impurities due to the discharge into them of domestic and industrial wastes.

To determine the degree of pollution, it is necessary to know the amount and character of the suspended wastes, the dissolved matter — both mineral and organic — microscopic organisms and bacteria. For the use of water by industries we are mostly interested in the mineral content,

though in some cases the organic nitrogen and bacteria may have a serious effect upon the manufactured product. Complete mineral analyses of the rivers of the state are very few, and where taken have generally been of separate samples, and not of samples collected over any extended period. In our work, we took full sanitary analyses of the Naugatuck and Hocka-



num rivers over a considerable period; and on the Naugatuck we have from records of factories full mineral analyses for similar points on the river, though taken at an earlier date. The results of these analyses are given in the following tables.

Number 1 in Table 1 is of the Naugatuck River at Torrington, before its use by the factories.

Number 2, after the river has received the wastes of Torrington, Thomaston, and Waterville, and has undergone whatever self-purification takes place before its use at Waterbury.

Number 3 is from the river at Waterbury, a little lower down.

Number 4 is from the Mad River, which enters the Naugatuck near where Number 3 was taken.

Number 5 is from the river above Ansonia and before its use by the factories of that city.

Number 6 is from the municipal supply at Ansonia and is introduced for purpose of comparison.

The analyses were taken monthly, May 1912, to May 1913, with the exception of the month of December.

The analyses in Table 2 are for the period June 1918, to June 1919.

Number 1 is from the river above Torrington.

Number 2, below Torrington.

Number 3, above Waterbury.

Number 4, at Waterbury, below the Mad River.

Number 5, above Ansonia.

Number 6, below Ansonia.

Number 7, the Mad River.

Table 3 gives analyses of wastes from copper and brass, the rubber, the iron and steel, the woolen, paper and silk industries.

Assuming that the samples above Torrington show the condition of the river with the natural impurities inherent to it, the effect of the discharge of industrial wastes should appear in the analyses lower down on the river.

The chemicals used in Torrington factories are acids, principally sulphuric, muriatic, and nitric, 1 242 000 lb.

Alkalies, mostly caustic soda and potash and sodium carbonate, 128 000 lb.; metal salts, principally sodium cyanide and bisulphite, zinc, nickel, and copper, 42 000 lb.; miscellaneous, 122 000 lb.

At Thomaston, acids 250 000 lb., alkalies 7 800 lb., metal salts, 1 400 lb., miscellaneous, principally soap, 24 000 lb. This makes a total—

Acids.	*Alkalies.*	*Metal Salts.*	*Miscellaneous.*
1 492 000 lb.	135 800 lb.	43 400 lb.	146 000 lb.

Comparing analyses, above Torrington in Table 1 with that above Waterbury, there is a slight increase in copper, silica, iron and aluminum oxides, lime, and soda; no increase in magnesia; the hardness is unchanged; a decrease occurs in free acid; a large increase, which would naturally be expected, in total sulphuric; chlorine increased and free alkalies decreased. Evidently considerable self-purification takes place between Torrington

TABLE 1.

Number. Location of Sample.	Copper	Silica. SiO_2.	Iron and Aluminia Oxides. $Fe_2O_3+Al_2O_3$.	Lime. CaO.	Magnesia. MgO.	Soda.	Total Solids.	Fixed Solids.	Volatile Solids.	Temporary Hardness.	Permanent Hardness.	Free Acids. H_2SO_4.	Total Sulphuric Acid. SO_3.	Chlorine.	Free Alkali.
No. 1. Maximum	0.0	16.3	12.6	11.3	5.6	11.5	109.9	58.4	54.6	5.4	24.9	20.0	8.4	6.0	9.2
Minimum	0.0	0.6	0.8	5.4	2.6	4.9	42.0	20.9	19.0	1.1	13.2	0.0	2.8	0.9	2.9
Mean	0.0	4.9	5.9	8.5	3.6	7.7	73.2	37.3	36.0	3.0	20.5	5.1	4.8	2.9	5.2
No. 2. Maximum	0.6	20.7	15.0	15.3	8.4	21.3	123.2	80.7	48.3	5.3	33.2	7.9	27.2	8.0	4.8
Minimum	0.0	0.9	3.1	4.6	1.6	4.8	46.7	24.4	19.3	0.7	11.6	0.0	5.8	1.2	0.0
Mean	0.08	6.9	6.8	9.4	3.6	9.9	81.2	47.8	33.4	2.9	20.4	3.2	12.0	4.1	2.4
No. 3. Maximum	1.2	42.9	44.5	19.1	6.3	35.0	219.7	168.9	83.8	11.4	47.4	9.6	70.4	19.3	0.8
Minimum	0.0	1.9	6.4	6.3	2.5	6.4	54.4	32.6	19.0	0.0	12.4	1.4	7.1	2.5	0.0
Mean	0.25	8.0	20.9	10.9	4.2	14.2	128.4	80.9	47.5	3.4	23.8	4.5	24.4	7.6	0.26
No. 4. Maximum	7.8	16.9	25.2	10.3	6.5	55.2	357.9	335.0	69.4	7.8	98.9	28.8	102.8	11.9	2.0
Minimum	0.0	2.1	4.4	4.1	2.0	7.1	80.1	45.8	22.9	0.9	13.2	2.6	12.4	0.7	0.0
Mean	2.18	9.4	10.9	7.3	3.1	24.9	151.0	109.3	41.6	4.3	42.7	11.5	45.8	6.3	0.66
No. 5. Maximum	1.4	12.4	12.8	23.3	6.2	33.5	172.8	137.2	60.4	7.4	42.8	38.8	56.0	14.0	3.2
Minimum	0.0	2.0	3.2	6.1	1.4	6.9	58.0	34.8	20.5	0.8	14.5	0.0	7.5	2.0	0.0
Mean	0.51	6.9	6.9	12.7	3.5	15.5	107.6	72.0	35.6	3.6	24.5	9.7	22.1	7.8	1.6
No. 6. Maximum	0.0	6.7	12.3	11.8	3.0	8.1	73.0	48.8	33.8	3.9	18.8	11.6	6.4	56.0	2.4
Minimum	0.0	1.4	0.7	3.8	0.7	3.8	32.8	10.8	11.4	0.1	9.2	0.0	2.0	7.5	1.2
Mean	0.0	3.3	4.4	5.5	1.7	15.6	45.8	24.8	21.0	1.6	12.6	3.9	4.1	22.1	1.7

TABLE 2.

Number. Location of Sample.	Free Ammonia.	Organic Nitrogen.	Oxygen Consumed.	Total Solids.	Total Suspended Solids.	Chlorine.	Alkalinity.
No. 1. Maximum	0.28	0.78	9.4	105	5	7.2	34
Minimum	0.05	0.21	6.6	42	2	2.4	14
Mean	0.12	0.51	8.2	74	4	4.7	23
No. 2. Maximum	1.72	3.87	14.0	282	91	11.7	35
Minimum	0.18	1.01	10.5	77	22	4.0	17
Mean	0.89	2.23	12.4	149	43	8.8	26
No. 3. Maximum	0.42	1.09	8.5	134	12	10.2	23
Minimum	0.08	0.19	5.2	39	3	4.1	10
Mean	0.18	0.59	6.2	80	7	6.3	16
No. 4. Maximum	1.93	3.12	14.3	309	37	14.2	17
Minimum	0.24	1.06	6.8	83	14	4.6	5
Mean	0.86	1.87	10.2	175	24	10.8	12
No. 5. Maximum	1.78	1.87	8.6	285	19	17.4	25
Minimum	0.18	0.78	7.1	77	9	5.2	10
Mean	0.89	1.25	7.9	147	12	10.2	16
No. 6. Maximum	2.19	1.90	9.2	237	16	17.3	28
Minimum	0.73	0.22	7.0	78	8	4.8	9
Mean	1.50	0.94	7.8	158	12	10.3	17
							+ −
No. 7. Maximum	1.09	2.35	17.2	243	57	16.5	17 23
Minimum	0.31	1.47	12.3	112	18	7.6	14 3
Mean	0.65	1.89	14.3	174	34	11.3	
							Av. −6

TABLE 3.

	Free Ammonia.	Organic Nitrogen.	Oxygen Consumed.	Solids.			
				Total.	Volatile.	Suspended.	
						Total.	Volatile.
Copper.							
Maximum	4.48	6.99	184.0	2 583	916	232	95
Minimum	0.05	0.22	3.1	138	28	11	1
Mean	...	1.74	24.0	803	295	51	26
Maximum	9.60	6.30	44.4	502	222	139	111
Minimum	0.08	0.91	3.9	185	37	26	20
Mean	2.27	2.35	20.3	316	102	68	49
Maximum	1.04	3.84	32.0	29 860	625	29 530	516
Minimum	0.11	0.43	17.1	905	153	630	58
Mean	0.36	2.93	23.4	7 621	335	11 093	258
Iron and Steel.							
Maximum	1.00	68.0	3 750	71 000	47 960	67 000	6 405
Minimum	0.34	0.2	82	1 050	255	160	80
Mean	0.67	17.8	890	25 510	11 309	15 236	2 729
Maximum	3.52	1.76	315	44 100	32 380	850	240
Minimum	0.52	0.08	7	550	270	0	0
Mean	1.33	0.75	85	11 356	7 862	266	72
Maximum	1.60	0.99	86	819	500	500	120
Minimum	0.08	0.20	3	140	30	0	0
Mean	0.56	0.69	25	416	138	133	27
Rubber.							
Maximum	4.32	23.52	570	1 625	999	1 395	960
Minimum	0.96	3.84	41	298	165	70	48
Mean	2.56	5.60	80	419	285	185	127
Maximum	7.2	43.5	870	7 105	6 010	5 792	5 772
Minimum	3.6	2.7	46	433	230	122	89
Mean	5.4	17.9	305	2 728	2 183	2 145	2 118
Maximum	16.8	75.5	3 100	14 091	5 945	602	386
Minimum	11.2	47.5	1 160	8 484	3 175	212	148
Mean	13.4	66.5	2 132	11 392	4 279	378	271
Woolen.							
Maximum	80.0	30.4	1 900	5 840	1 630	1 280	785
Minimum	0.08	1.2	49	217	144	50	40
Mean	14.5	11.1	822	2 554	1 264	408	324
Silk.							
Mean	2.32	590	3 220	36 800	14 400	8 400	7 000
Paper.							
Maximum	2.2	14.8	421	5 400	2 720	730	539
Minimum	0.08	0.09	20	260	90	110	73
Mean	0.49	4.80	153	1 047	591	324	226

TABLE 3. — *Continued.*

	Chlorine.	Alkalinity. $CaCO_3$.	Iron.	Copper.	Sulphates. SO_4.	Dissolved Oxygen Demand.	Remarks.
Copper.							
Maximum..	86.5	28	...	555	1 358	...	Pickle and
Minimum...	3.0	−715	...	3	36.8	...	Dip Rinse
Mean.....	20.2	−161	...	54.6	373	...	Waters.
Maximum..	26.0	87	...	5.6	110	...	Plating
Minimum...	3.5	23	...	0.4	33	...	Rinse
Mean.....	15.1	56	...	2.3	67	...	Waters.
Maximum..	133	290	...	332	...	...	
Minimum...	22.5	22	...	12	...	...	Tailings.
Mean.....	78.7	124	...	109	...	...	
Iron and Steel							
Maximum..	5 000	33 000	1 300	...	...	...	Cleansing
Minimum...	140	120	1.2	...	...	...	Rinse
Mean.....	1 803	7 814	275.4	...	...	...	Waters.
Maximum..	1 250	−70	520	...	5 460	...	Pickle and
Minimum...	8	−20 500	4	...	175	...	Dip Rinse
Mean.....	395	− 4 163	212	...	2 349	...	Waters.
Maximum..	120	128	6.4	...	...	...	Plating
Minimum...	40	−70	0.0	...	...	...	Rinse
Mean.....	68	25	2.9	...	...	...	Waters.
Rubber.							
Maximum..	28.0	100	...	...	...	115	Crude
Minimum...	4.5	16	...	...	...	10	Rubber
Mean.....	14.5	38	...	...	...	20	Washings.
Maximum..	170	−60	...	...	...	3 745	Acid
Minimum...	5	−3 100	...	...	...	342	Room
Mean.....	75	−999	...	...	...	2 043	Waters.
Maximum..	149	2 540	...	...	...	1 926	
Minimum...	28	−575	...	...	...	1 653	Tank
Mean.....	82	814	...	...	...	1 790	Effluent.
Woolen.							
Maximum..	150	3 200	...	...	...	...	
Minimum...	3	60	...	...	...	...	
Mean.....	51	1 003	...	...	...	...	
Silk.							Concentrated
							Composit
Mean.....	...	...	...	...	...	...	Sample.
Paper.							
Maximum..	108	390	...	...	...	...	
Minimum...	5	12	...	...	...	...	
Mean.....	36	82	...	...	...	...	

and Waterbury, and this is confirmed in Table 2. In the analyses below Torrington there was a decided increase in all the determinations except alkalinity, while in the analyses above Waterbury there was a very noticeable decrease.

The amounts of chemicals used, pounds per annum, in Waterbury, including Waterville and Watertown, were —

Acids.	*Alkalies.*	*Metal Salts.*	*Miscellaneous.*
8 693 507 lb.	1 185 982 lb.	2 316 015 lb.	10 921 785 lb.

The analyses in Table 1 show a decided increase in the copper, iron and aluminum oxides and soda. Total and mineral solids, total sulphuric acid, and the chlorine, silica, lime, magnesia, hardness and free acid were slightly increased, and free alkalies showed a decided decrease. In Table 2 all determinations were noticeably increased except the alkalinity.

The amounts of chemicals used in pounds per annum at Naugatuck, Beacon Falls, and Seymour were —

Acids.	*Alkalies.*	*Metal Salts.*	*Miscellaneous.*
7 374 000 lb.	1 184 000 lb.	243 000 lb.	12 213 000 lb.

The analyses of the river above Ansonia compared with those below Waterbury show marked decrease in all constitutents except the soda and free alkalies, which show an increase. In Table 2 all determinations are decreased except free ammonia and alkalinity. Self-purification has again evidently taken place.

In this connection it is interesting to compare analyses of the Mad River with analyses of the Naugatuck above and below its entrance. In Table 1 the copper, soda, total and mineral solids, hardness, free acid, total sulphuric acid and chlorine were considerably above those in the Naugatuck, the silica only slightly and the iron and aluminum oxides, lime, and magnesia considerably less. The large increase in free alkalies is particularly noticeable, and no explanation suggests itself. In Table 2 the analyses of the Naugatuck below the entrance of the Mad River show an increase in the free ammonia, organic nitrogen, and total solids; a decrease in oxygen consumed, suspended solids and chlorine and a marked change from acidity to alkalinity. The beginning of the absorption of the heavy pollution of the Mad River by the Naugatuck is noticeable from these results, and this action apparently continues in spite of the added pollution lower down.

The amounts of chemicals in pounds per annum used at Ansonia were

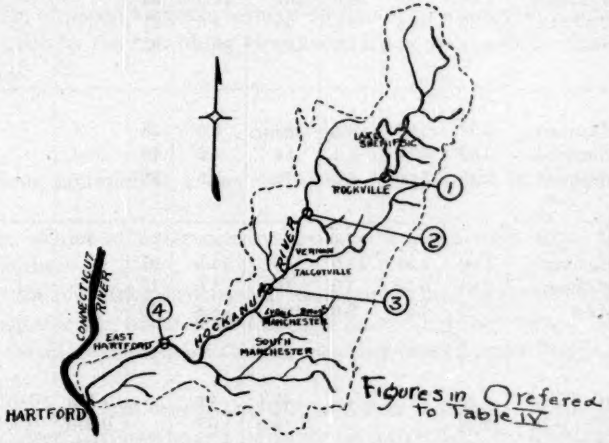
Acids.	*Alkalies.*	*Metal Salts.*	*Miscellaneous.*
1 945 101 lb.	21 123 lb.	25 062 lb.	627 270 lb.

Full mineral analyses of the river below this city are not available, but the sanitary analyses when compared with that above the city show an increase in the free ammonia and total solids, a decrease in the organic

nitrogen and slight changes in oxygen consumed, suspended solids, chlorine, and alkalinity.

Comparing analyses of the copper, iron, and steel and the rubber wastes with the river water, it is noticeable that while the free ammonia in waste waters from the rubber industry was as high as 16.8 p.p.m. and organic nitrogen 75.5 p.p.m., in the river below they were only 1.78 p.p.m. and 1.87 p.p.m. In the waste waters from the iron and steel, oxygen consumed ran as high as 3 750 p.p.m., total solids 71 000 p.p.m., chlorine 5 000 p.p.m., alkalinity 33 000, iron 1 300 p.p.m., acidity 20 500 p.p.m.; while in the river, taking them in the same order, the highest figures were 14.3 p.p.m.. 309 p.p.m., 14.2 p.p.m., and 17 p.p.m. Even in the Mad River the acidity never exceeded 23 p.p.m.

The explanation for this would appear to be the effect of dilution when mixed with waters of the Naugatuck and the opportunity afforded for sedimentation by the numerous mill ponds.



HOCKANUM RIVER
MAP OF WATERSHED

Unfortunately, full mineral analyses of the Hockanum River are not available, but Table 4 gives results of sanitary analyses for the period from July 1918, to July 1919.

No. 1 is at Lake Schenipsit.

No. 2 is below Rockville.

No. 3 is above Manchester.

No. 4 is at Burnside, below the entrance of the South Branch, on which are located large silk mills and paper companies.

No. 5 is analyses of rain water, collected at the Yale Medical School, New Haven, during 1889–1890. The quality of water suitable for use in

the woolen and paper industries is often described as that akin to rain water, and this is introduced here for comparison with water from Lake Schenipsit, which is considered satisfactory.

TABLE 4.

	Free Ammonia.	Organic Nitrogen.	Oxygen Consumed.	Total Solids	Chlorine.	Alkalinity	Albuminoid Ammonia.	Nitrites.	Nitrates.
No. 1. Maximum..	0.19	0.82	6.6	92	7.0	15	...	...	...
Minimum..	0.00	0.22	1.2	23	1.5	9	...	...	...
Mean.....	0.08	0.46	4.9	47	4.1	13	...	...	...
No. 2. Maximum..	1.68	2.82	26.0	207	16.5	55	...	...	...
Minimum..	0.29	0.38	5.8	56	5.0	21	...	...	...
Mean.....	0.73	1.33	11.2	122	10.2	38	...	...	...
No. 3. Maximum..	0.37	2.06	9.7	89	6.5	28	...	...	...
Minimum..	0.02	0.56	3.4	54	4.0	18	...	...	...
Mean.....	0.15	0.90	6.5	76	5.6	22	...	...	...
No. 4. Maximum..	1.09	1.81	13.0	170	14.5	47	...	...	...
Minimum..	0.04	0.32	5.0	56	5.0	17	...	...	...
Mean.....	0.50	1.01	8.0	105	8.8	35	...	...	...
No. 5. Maximum..	5.20	...	...	47.4	4.6	..	0.142	0.010	0.16
Minimum..	0.34	...	...	18.0	0.7	..	0.050	0.001	0.02
Mean.....	0.83	...	...	13.4	1.77	..	0.071	0.005	0.06

Obviously rain collected from an atmosphere laden with the gases and fumes from a manufacturing community is quite different from that collected where the air is free from such contamination. In these analyses the rain was collected monthly for fourteen months. The solids and nitrogenous matter are much larger that we would expect to find in a pure water.

The chemicals used in the factories at Rockville, in pounds per annum, are,—

Acids.	*Alkalies.*	*Metal Salts.*	*Miscellaneous.*
123 000 lb.	479 000 lb.	184 000 lb.	823 000 lb.

Acetic and sulphuric predominate in the acids, soda ash in the alkalies, compounds of sodium in the metal salts, and soap and dyestuffs in the

miscellaneous. All the determinations show a noticeable increase below Rockville.

The chemicals used in Manchester, in pounds per annum, are,—

Acids.	*Alkalies.*	*Metal Salts.*	*Miscellaneous.*
329 000 lb.	226 000 lb.	797 000 lb.	2 763 000 lb.

Sulphuric predominates in the acids, soda ash in the alkalies, iron in the metal salts, and soap and dyestuffs in the miscellaneous.

All the determinations, excepting organic nitrogen and oxygen consumed, show a decided increase in No. 4 over those in No. 3.

Comparing the analyses of the woolen, paper, and silk wastes with analyses of river water, the marked decrease in oxygen consumed, total solids, chlorine, and alkalinity is noticeable. This is partly accounted for by the passage of the woolen wastes at Rockville and the silk wastes at South Manchester through the sewage treatment plants and the sedimentation of paper wastes in lagoons on Lydall Brook and in Union Pond. The dilution by the flow of the Hockanum River undoubtedly effects some reduction.

Conclusions.

Stream pollution is a very important factor in the industrial use of water.

The volume of water used industrially is about three times that for domestic use.

For the industries discussed in this paper, it may be assumed that any water suitable for boiler feed purposes in one industry would be satisfactory for all. The opposite is true for other uses of water by the several industries.

In the brass and copper and iron and steel industry, a water suitable for boiler-feed purposes would probably be satisfactory for manufacturing uses. Excessive amounts of organic and suspended matter and free acid would be objectionable.

The water of the Naugatuck River can be used in its present condition in these industries.

In the manufacture of articles from crude rubber, presence of acids is undesirable; in cooling process, organic matter, if finely divided, is not objectionable.

In regeneration of rubber, condition of water has very little effect, and the condition of the Naugatuck River, as it is, is not considered objectionable.

The woolen industry requires a "soft" water; calcium and magnesium compounds are detrimental. They prevent a proper lather from the soap, and tend to form insoluble precipitates. The water from Lake Schenipsit has always been found satisfactory.

The paper industry requires a water free from acids, suspended matter, high color, iron, calcium and magnesium, and organic matter. A very soft water is sometimes detrimental. In the manufacture of the coarser grades, a small amount of suspended matter is allowable. The waters of Lydall Brook have been found satisfactory for the manufacture of leather board, while the waters of the Hockanum River at Burnside require treatment before use in the manufacture of tissue and waxed papers.

Excessive hardness and high color, organic and suspended matter and iron are detrimental to the silk industry. For about two thirds of the work, hardness of 30 p.p.m. and color of 25 p.p.m. is allowable. In some special processes these must be reduced to zero.

Bleaching and dyeing require a clear, soft water, as near akin to rain water as possible. Calcium and magnesium, and even a trace of iron, is undesirable.

The wastes from many industries using similar processes do not pollute a stream so as to prevent its use industrially by allied industries.

For example, one brass or copper, iron or steel, or rubber factory on the Hockanum River would affect very seriously all the industries lower down, but the woolen factory in Torrington apparently does not affect the use of the river, one way or the other, by the brass companies.

The absorption by the rivers of the high polluting constituents of the various wastes is materially affected by the volume of flow and the opportunity offered for sedimentation by treatment plants or in mill ponds.

Many factories were located on rivers before the effect of pollution was evident. Locations were determined more by the volume of flow and suitability of water for steaming purposes than for its effect on manufactured articles.

The removal of pollution would undoubtedly be beneficial in its effect on boiler efficiency in all the industries.

No intensive studies have been made of the effect of pollution on the chemicals used or on the manufactured articles.

It is known, however, that some chemicals used in the woolen, paper, silk, and bleaching and dyeing industries are seriously affected by free acids, high color, large amounts of suspended matter, appreciable amounts of iron and organic matter, fecal or non-fecal.

The copper and brass and iron and steel industries are affected only by suspended matter.

The rubber industry appears to be affected the least of any by pollution.

The efforts of most manufacturers have been directed towards savings effected in obtaining a water suitable for steaming purposes. Little, if any, attention has been given to reducing cost of production and increasing value of product by removal of stream pollution.

It is known that calcium and magnesium decompose equal amounts of many chemicals; that waters containing iron are liable to develop brown gelatinous growths that affect cleansing processes where soap or alkalies

are used; that the bleaching power of certain chemicals is affected by chlorine.

The study of waters suitable for steaming has demonstrated that a considerable saving can be accomplished either by care in selecting a satisfactory supply or by treating an unsatisfactory one. Stream pollution must cause waste. The large amounts of chemicals used in the Naugatuck and Hockanum valleys should warrant intensive study of the effect of pollution on chemicals used.

Entirely aside from the general benefit to public health and comfort, the removal of stream pollution would be beneficial and effect savings in the use of water for steaming and and other industrial purposes.

Acknowledgment for some of the information used in preparing this paper is due W. H. Bassett, of the American Brass Company; John Goss, of the Scovill Manufacturing Company; Walter M. Scott, of Cheney Brothers; Herbert J. Regan, of the James J. Regan Company; T. R. Appell, of the Warrenton Woolen Company; O. L. Johnson, of the Aspinook Company; N. G. Read, of the Burnside Mills; C. F. McCarthy, of the Goodyear Metallic Rubber Shoe Company, and E. A. Andersen, of the Rubber Regenerating Company.

Discussion.

Mr. Harrison P. Eddy.* Mr. President, Mr. Jackson very kindly placed in my hands a copy of this paper just before the meeting. I have not had time to consider it in detail. However, it is very evident that this extensive study has furnished much valuable data on an important subject.

In connection with the water consumption, on page 15, Mr. Jackson, I assume that the figures given in the second part of the table are consumption for domestic purposes.

Mr. Jackson. That is right.

Mr. Eddy. The thing which of course at once appeals to one studying this subject is the very large volume of industrial wastes and the very great quantity of waste materials which go into the streams with the water. It is remarkable that our rivers will assimilate and dispose of so much of this material without creating more objectionable conditions than appear to be the case, not only from this study but from others of a similar nature.

Mr. Stephen DeM. Gage.† In some of the western states, notably in Illinois, the state has taken upon itself to make studies of the waters of the state, not only of streams but also of the ground waters and the public water supplies, in relation to their uses for industrial purposes. It seems to me that this is a very important thing for the state to do. Our New England states have not done this as yet, but there is a demand for something of the kind.

---

* Of Metcalf & Eddy, Boston.

† Chemist and Sanitary Engineer, R. I. State Board of Health.

I suppose I get, on an average, four requests a month from industrial concerns for information of one kind or another about the quality, either of some of our rivers in Rhode Island or some of our public water supplies, in relation to their use for some specific industry. Of course our larger industries, particularly those using large volumes of water, are located on the larger streams, and their requirements are pretty well defined. But there are many small industries — that is, industries requiring relatively small amounts of water — in which the chemical and other characteristics of the water supply are very important. Many of our newer industries which are growing rapidly are based on chemical processes which may be affected by the characteristics of the water used. It seems to me that it should be the duty of the state to have full information of this kind available for the use of prospective manufacturers. If a new industry which is just being developed is to come into your state it may mean a great deal to the industrial life of your state in one way or another, and the state should be in a position to aid that industry in determining where it is best to locate.

This of course is an economic problem, not a public health problem, and our state laboratories have usually been developed along public health lines. But with a minimum expenditure of funds the work of our state laboratories and our sanitary water surveys could be extended so as to obtain a great deal of information which it seems to me might be of very great economic importance.

MR. M. N. BAKER. * I want to express appreciation of the studies that have been made in connection with this matter, and to voice the hope that such studies may be continued in Connecticut and elsewhere, as being of great value. The studies seem to be unique from the points of view that have been taken. Heretofore most stream pollution studies have been directed against pollution, and this seems to be a broader study, as it takes into account the water supplied to the industries and the whole range of important elements involved.

MR. EDDY. The importance of an adequate supply of suitable water and practical means of disposing of wastes for industries has come to be a very important matter, particularly in communities devoted largely to manufacturing. This subject, which formerly was given comparatively little weight in the selection of industrial sites, is now often carefully considered before the establishment of an industry in any particular locality.

In many cases, however, it is difficult, or impossible, to predict what the future conditions will be. A water which is suitable to-day may be so altered in the future by the discharge of wastes from some new or enlarged industrial plant, that its usefulness will be seriously inpaired. An industry which is established with a view to the discharge of untreated wastes into a river may soon find itself embarrassed by the erection, further down

* Associate Editor, *Engineering News Record*, New York.

stream, of a new industrial plant which requires a better water than that flowing past its property. It then becomes necessary to treat the wastes of the upper plant and perhaps also to treat the water used by the lower industry. In some cases, such treatment imposes a serious financial burden, and in others it may be considered impracticable to so treat all of the wastes that the waters into which they are discharged may be suitable for use in certain industries.

In many cases, lower riparian manufacturers hesitate to resort to the courts to secure treatment of wastes discharged into the river above, even though the law appears to be clear that they are entitled to receive the water in its natural condition, subject only to reasonable use by upper riparian owners. Accordingly, considerable courtesy is often extended to upper manufacturers, although many such cases have been litigated.

The increase in manufacturing and the decrease in the number of available suitable sites for the establishment of industries using process waters is gradually leading to a demand for some regulation of the quality of our streams. It is highly desirable that rivers be maintained in proper condition, but to determine what is the *proper condition* is exceedingly difficult. In some cases it is probable that this should be determined by the uses made of the river by the public and by considerations of public comfort. In other cases, perhaps the requirements of all the riparian manufacturers should control, and in some localities the agricultural interests may predominate and require that the waters be maintained suitable for watering stock and for irrigation.

It seems certain that the same standard of purity cannot wisely be adopted for all rivers, and that each stream must be considered under its own peculiar environment and conditions.

The first logical step in all cases must be to ascertain the conditions and needs. This can be done by investigations similar to those which have been made in Connecticut, under Mr. Jackson's direction. The accumulation of such valuable data will greatly assist in the correct solution of this very intricate problem.

MANGANESE BRONZE FOR VALVE STEMS.

BY WILLIAM R. CONARD.*

[*Read September 14, 1921.*]

This paper is chiefly concerned with valves as used for water-works purposes, so that the type or quality of valve stems as used in valves for other purposes will not be mentioned here.

Early water valves or devices for shutting off the flow of water in pipe mostly had a shaft or stem for operating the gate made of wrought iron, and even up to comparatively recent times some water works have continued to use wrought iron. However, for a fairly long period the use of a brass or bronze stem has been the custom, because of its non-corroding qualities. The early substitutes for wrought iron were largely common brass; then, in order to get greater strength, bronzes were resorted to, the best of which was known as the " Government mix " of 88 parts copper, 10 parts tin, and 2 parts zinc, and even yet some of our water works and manufacturers are satisfied with this material for the valve stems. The next step in the use of an alloy metal for valve stems was the adoption by some users of " Tobin bronze " and its companion metal, " Naval bronze." Tobin bronze is a patented trade name for a rolled bronze; Naval bronze is also a trade name for practically the same metal. Both of these bronzes, because of being worked or rolled after being cast into ingots and rolled into billets, present a more uniform texture than the same mix in cast form, and considerably increased strength, particularly in the smaller diameters and where they can be used without cutting away too much of the outer skin or section, which is the part which has the greatest strength, for, when the inner section or core is cut into, the strength decreases quite rapidly, though this is true of practically all bronzes, though in some to a lesser degree. There are a number of water works which regularly specify for their valve stems one of the rolled bronzes. One of the drawbacks to their use is in the difficulty of getting a proper collar on the stem for valves of the inside screw type, which are largely the only ones used in water works.

At about the time some water works commenced to specify the rolled bronzed for valve stems, some of the makers commenced making part of their output of stems of manganese bronze, but with indifferent success, as the production of manganese bronze is a specialty in itself and requires that it be made with the knowledge and studies which have been given it by those who specialize in its production. It can be produced to give

* Inspecting Engineer, Burlington, N. J.

practically any combination of physical characteristics desired, such as free machining qualities with moderate tensile strength and yield point, or much higher tensile strength with a combination of either high ductility and low yield point or low ductility and high yield point.

Confining ourselves primarily to gate valves for water-works purpose we find that the valve is made up of such parts as — body, seat rings, dome or cover, gates, face rings, wedging mechanism, stem, stuffing box, stuffing-box follower or gland, stem nut, gears in the case of larger valves, packing and gaskets, bolts and nuts, and in the case of what are termed " rising stems " the " yoke " and its parts.

Of these thirteen or more parts, the most important one is the stem, for upon it depends the proper opening and closing of the gate or gates and the operation of the wedging mechanism, which in turn controls the flow of the water, and if the stem fails the rest of the mechanism is practically useless. This is also in part true of the other parts, yet unless there should be a complete failure of the body, the other parts with the stem intact might function in part.

The actual work that the stem performs is lifting the load or weight of the gates, and the wedging device, overcoming the friction of the gates against the seats and the wedges in starting to open with the gate closed; the friction caused by the pressure of the water in the pipe during the later part of the travel in closing; the friction of water seal or packing in the stuffing box, and the friction of the threads on the stem working through the stem nut. The stresses set up depend on the pressure of the water against the gates and are tension on the body of the stem, shear on the threads and collar, and torsion, to a greater or less degree, during the entire operations of opening and closing.

The tension coming as it does on the body of the stem, the controlling diameter or cross-sectional area is that at the bottom of the thread, the shear controls the area of metal of the total amount of metal engaged in the thread of the stem nut when operating, and of the collar operating in its recess between the top of the bonnet and the lower part of the stuffing box, and the torsion is largely on the cross-sectional area of the stem at the base of the threads. Therefore in determining the diameter of the stem the area at the base of the thread should control, and not the full diameter of the stem, and high factors of safety should be allowed to provide not only for these stresses but also for the human element, which always enters in a device of this kind, and which is not always operated by persons who appreciate the importance of the fact that a valve is a machine and not simply a mass of metal that can stand all sorts of abuse.

In years past the big advantage of controlling and obtaining flexibilty of a water system by a comprehensive system of valves did not seem to have as large a place in the planning and in the construction of our water systems as it has to-day. What valves there were, were probably not operated as frequently as at present, so that while they had their

valve failures they were not particularly numerous; while nowadays with the need for conservation, and the desire to be efficient, more frequent inspection causes the valves in our water works to be operated at shorter intervals, with the accompanying stresses as before described placed on the stems at shortening intervals.

When wrought iron was used for stems, and the valve operated at irregular and fairly long periods, being of a metal that probably had a breaking strength of around 40 000 lb. per square inch, not a great deal of difficulty was had. Then when brass came into use, having very much less strength than iron, it was soon discarded in favor of bronze of about the 88-10-2 type, which gave some additional strength and greater ductility, the ductility of valve stems having been thought at this period to be an important factor.

It is entirely true that if there were nothing but the tension and torsion stresses that need be considered, ductility would be of very great importance, but there are other conditions which often develop that make high ductility not only unnecessary but often dangerous.

For example, when the stresses on a valve stem become great enough to exceed the " elastic limit " of the metal, the stem commences to distort, either elongating, buckling, or twisting, and with the load removed the stem remains distorted because the limit of its elasticity has been passed. Now in bronze, while it is possible to produce it with a high " elastic limit or point of yield " and a high ultimate strength, the ductility is reduced; whereas to attain a high ductility while a fairly high ultimate strength may be retained the yield point drops to a comparatively low point; in other words, generally speaking, the yield point and elongation vary with each other inversely. This, then, brings us to the point where we must decide whether we desire a metal of high yield point and enough ductility so that we do not get a failure without warning and with, of course, a good high ultimate strength; or whether we will sacrifice the higher yield point and obtain a metal that will flow or yield extensively before breaking. After giving the matter extended study and consideration, I have come to the conclusion that the best bronze for valve stems is that which has the characteristics of high yield or elastic limit, moderate ductility, high ultimate strength, but not more than 100 per cent. higher than the yield point.

My reason for this conclusion is that immediately a stem is distorted by stressing it beyond the point of yield, whether it be stretched, buckled or bent, or the pitch of the thread upset, the valve is rendered practically useless until a new stem is put in, and if a metal can be obtained which because it has the virtue of a high elastic limit, thereby placing the likelihood of a distorted stem in the range of improbabilities, I feel that the valve is that much nearer being fool proof, and that the efficiency of the water-works system in which such valves go is thereby increased.

And the one good thing about all of this is that it is being done at practically no increase in cost, for stems having the qualities of high elastic

limit, high ultimate strength, moderate ductility, cost little if any more than those that have high ductility, moderately high ultimate strength, comparatively low elastic limit. It is not particularly difficult to get a bronze that will have a yield point of not less than 40 000 lb. per square inch, an ultimate strength of 60 000 lb. to 70 000 lb. per square inch, an elongation percentage of 10 in 2 inches, a reduced area percentage of 10; and, with the importance of having the stem retain its original shape understood, surely that is better than getting a metal which has a yield point of not over 25 000 lb. per square inch, an ultimate strength of around 50 000 lb. per square inch, an elongation of around 30 per cent. in 2 inches, a reduction of area of around 25 per cent.

It is hoped you catch the point I am trying to make, which is that the water-works official and the manufacturer usually base their calculation on the ultimate strength of the material, figuring that the usefulness of the stem is not gone until it actually fails.

This harder, stronger metal is of course somewhat tougher and not quite so easily machined, but if the proper tools are used it doesn't appreciably increase the cost, and surely is better than increasing the size of the stem beyond the manufacturer's standard, to get the added strength.

The more frequent reasons for valve-stem failures are that, as indicated, the factor of necessary strength is mostly based on the full diameter of the stem; the tensile or ultimate strength of the metal, and not taking into account that metals of any kind, unless especially treated for it, do not have as great strength in the center or core of the mass as near the surface, with the result that a stem has scarcely any greater strength at the bottom of the thread than the simple working stresses that are put on it, without taking into account added friction due to corrosion, sediment, etc., nor that in many cases the persons operating are likely to use tools that exert considerably greater leverage on the gears or operating nut than is intended or needed.

Therefore to overcome these failures, so far as humanly possible within reason, the calculations for valve stem diameter should be:

Allowance for the fact that the metal at the base of the thread does not have as great a strength as near the surface or the top of the thread; a further allowance for the use of tools for operating, which will exert greater stress than the usual tool used; together with allowances for friction due to corrosion or sediment in the water, and other factors mentioned earlier, of weight of mechanism, friction of gates and seats in operation, and friction in stuffing box, controls the area at the base of the thread, and also that a liberal allowance should be made the governing feature for factors of safety, and the metal should have a high yield point, a fairly high ultimate, and moderate ductility.

In order that the physical qualities of the bronze may be known and kept uniform, it is very important that frequent tests be made. The proper way to get the pieces for testing so as to have them as truly repre-

sentative as the stems themselves, is, where the stem is cast and large enough to do so, to have the piece for testing cast attached to the actual stem, and where the stem is of a size to make this impossible the test piece should be cast in the same heat and in the same flask as the stems. In the case of hammered or forged stems, the test piece should be a prolongation of one end of the stem reduced to a cross-section that will show a close approximate of the metal in the stem itself. It is unnecessary to go into the details of the methods of making the physical tests.

For smaller and medium-sized valve stems up to and including those for, say, 24-in. valves, a cast stem is entirely proper, but for stems for valves 30 in. and larger they should be of forged manganese bronze. Forging adds very little to the cost and adds some to the physical qualities, but their main value lies in that the forging on stems of heavy cross-section makes the metal homogeneous and of uniform texture throughout, makes a perfect metal for the threads and eliminates the uncertainties that are apt to be present in the case of large castings, where the central section is subject to different cooling stresses than the outer section.

In the foregoing I have endeavored to demonstrate the advantages of using a high-grade manganese bronze for your valve stems, and to explain that by specifying such metal no hardship is being placed on the manufacturer; in fact, if he will but stop and think it will work ultimately very much to his advantage, for what manufacturer is there that would not rather have his product praised than condemned, and his attention can be given to producing new goods, and not have to use part of his shop facilities for repair parts, for there are things that can happen to a valve outside of the stem that can be readily traced back to the stem. And to you men who use valves, by exercising care and specifying for your stems bronzes that will have high physical values, you will establish a standard which will work a considerable economy, — economy of cost, economy of long life, economy of efficiency, economy of insurance against property damage and even possible loss of life. Your coöperation and efforts, together with the coöperation of those who supply your valves, is the thing that will accomplish this.

Discussion.

Mr. J. M. Diven.* While fully agreeing with the writer of the paper that the stem is the weak point in a valve, and that they are most often put out of commission by the breaking or buckling of the stem, and that the stems should be made of the best available material and of the greatest strength consistent with economical manufacture, the speaker cannot fully agree that they are the only part of a valve mechanism that will by breaking put a valve out of commission, for the breaking of a wedge, especially the top one, or of the bushing or nut in the wedge, will quite as effectually render the valve useless as the breaking of the stem. If there is nothing for the stem to act on it cannot operate the valve.

The writer says that, in the days when valves were widely scattered on the distribution systems and controlled large territories or length of mains, they were used infrequently and were more apt to rust or set owing to inaction than with the present practice of many valves controlling short lengths of main. The reverse would seem to be the case, for two valves in present practice control each block; if they had to be used to shut down five or ten blocks there would be five or ten times more liability of leaks on the pipe lines controlled by them than if there were valves for each single block. Of course we do not now allow valves to stand idle till needed to shut off for repairs, but make frequent tests of them, which was, probably, not so universally the case in the old times.

Mr. Patrick Gear.† The trouble I find with the stem is not in the stem altogether, because you can bend that up and down for a month and the stem won't break. But instead of talking about metal for the stem, if we would only tell the manufacturers how they ought to make their gate and get them to make it properly, we would not have any trouble with the stem.

I do not think I am stepping on their toes when I tell them that there is not any improvement over the gate that they made forty years ago in the gate they are making to-day. They may test the stem and have a little better metal in it. Some of them tried to put a steel rod in the stem, some years ago, but they did away with that. If they will make the gate so that there will not be any corrosion and the rust won't come against the gate when you shut it and open it, there will be no trouble.

Mr. Van Gilder speaks of shutting and opening the gate when he has the leak. We all have that trouble of opening and shutting the gate. If the manufacturers would only make the gate properly, so that corrosion would be kept away from the face, they would be all right. I have taken off some gates that were in for forty years, and the trouble I found with one of them was that the cast-iron stuffing box had such a grip on the stem that it could not be opened and shut. And still they put a cast-iron

* Secretary, American Water Works Association.
† Superintendent, Water Works, Holyoke, Mass.

gland and stuffing box on to-day, and it is all cast iron around a brass stem, and they expect, when the packing is worn out, that it can be made tight.

If they would only make their gates all brass, so that there would not be the cast iron and brass working together, you would not have all the trouble you do.

MR. DIVEN. I know of some 30-in. valves all composition. They are making them to-day.

PRESIDENT SHERMAN. I guess they will make bronze valves if you want to pay for them.

MR. C. P. DAVIS.* I would like to ask Mr. Gear if he uses any grease on those stuffing boxes.

MR. GEAR. Not on those that have been in the ground for thirty or forty years, in concrete streets. When we put in a new gate we use all the precaution that is required. You need brass bands, brass bolts, and brass nuts to get the best stuffing box, with brass lining under the shoulder of the spindle, — the top of the gate where the shoulder sets down. Forty years from now there will be no trouble, because there is no packing there now. The shoulder of the spindle up against the brass lining of the top of the gate will make it tight.

MR. DAVIS. I think there is much to be gained from the lubrication of those parts. We have the cast iron against the brass or bronze, or whatever it is. We all know that the great majority of the valves have very little provision for lubrication. Isn't it time that we took some step not only to see that we get proper lubrication in new valves but to lubricate the valves already on hand?

PRESIDENT SHERMAN. Can you do much in the way of lubrication of a valve that has only a cast-iron gate box over it? I believe the majority of our valves have only the cast-iron box.

MR. DAVIS. Shouldn't we provide some covering, like a waterproof tar or cotton stock?

PRESIDENT SHERMAN. I was wondering how you expected to get the grease into it.

MR. DAVIS. I think all valves should be in a box large enough to give easy access, without breaking the pavement, to the mechanical parts of the valve. Pavements are becoming more and more costly. It probably costs $25 or $30 every time you break the pavement. I think it pays to put them in a valve box.

PRESIDENT SHERMAN. I think that is a great point, but most of us are not doing it in small places.

MR. DAVIS. At present prices it costs about $30 or $40 to make a good valve box, to give you access to all the mechanism of a large valve, and completely to the small valve.

PRESIDENT SHERMAN. What kind of box do you use?

---

* Chief Bureau of Water, Philadelphia, Pa.

MR. DAVIS. We use a reinforced concrete box of sectional rings. The bottom course is split to straddle the pipe, and subsequent courses are split on opposite axes for bonding. The cover is a reinforced concrete slab about 4 in. thick, with a hole for the cast-iron manhole frame and cover similar to that used for sewers. The box is about 2 ft. by 3 ft. inside.

MR. DIVEN. I used one of cast iron. I don't know whether it is still on the market or not. You can build it up to any size you want. It allows space to get into, to oil the valve or take the stem out of an upright valve. In one case I had a valve that gave a great deal of trouble. The stem gave out twice and I had to take up a lot of concrete paving. The last time I fixed the valve I put a piece of 4-in. pipe in so that the stem could be run out into this 4-in. pipe to save tearing up the street if we had further trouble.

A RATING OF THE QUALITIES OF THE WATER SUPPLIES OF MASSACHUSETTS.

BY GEORGE C. WHIPPLE.*

[*Read September 15, 1921.*]

It is a long time since a critical review of the water supplies of Massachusetts with reference to quality has been published. The State Department of Public Health has continued to make analyses of samples of water in much the same way as they were begun thirty years ago, but in recent years fewer samples from each source have been analyzed and some of the early tests have been omitted. Parsimony in state printing has made it necessary to emasculate the reports of laboratory work, with the result that the Department of Public Health has lost in prestige, the public is not as well informed in regard to the quality of the Massachusetts supplies as it once was, and the records are not as readily available for scientific study as they ought to be. In 1891 the annual report of the State Board of Health devoted 190 pages to the analyses of domestic water supplies; in 1901, 98 pages; in 1909, 52; and since that date, 8 pages. The last comparative study was published in 1909. For the last ten years, only the yearly averages of a portion of the tests made in the laboratory have been published.

It is not now necessary to publish the analyses in the detailed manner of thirty years ago, when the subject was new, and it is not necessary to print each year comparative average figures for the previous years, as was formerly done; but the public is entitled to have, and ought to have, something better than it now gets. A satisfactory plan might be to publish each year the results for that year, making mention of any abnormal or unusual conditions, and then once in five years to publish comparative tables of the analyses for the previous five years, accompanied by a critical review of the qualities of the different water supplies. According to this plan, a quinquennial review of the water supplies for the five years ending December 31, 1920, would now be due; but inasmuch as no such summary of reports was made in 1915, this should cover a ten-year instead of a five-year period.

Since the last comparative tables were published in 1909 there have been almost no changes in the art of chemical analysis which it has seemed worth while to introduce in the State Department of Health laboratories. The Committee on Standard Methods of Water Analysis of the American Public Health Association has suggested certain minor modifications in methods of procedure, but their adoption would have made it difficult to

* Professor of Sanitary Engineering, Harvard University.

compare the new results with the old and, because of the long series of analytical records in Massachusetts, uniformity with the past seemed to be more important than uniformity with methods used in other states. For the same reason also the method of stating the results in parts per 100 000 instead of parts per million has been adhered to, although the writer personally favors the latter method and has used it in this review.

Bacteriological methods have never been held to the same rigid system which has been followed in chemical analysis. There are more uncontrollable variables in bacteriological work. In these tests the Department of Public Health has followed the changes recommended by the Committee on Standard Methods in a general way, but these changes have been so frequent that it has not seemed wise to break continuity with past records too frequently.

While improvements in methods of analysis have not been great, a decided change has taken place in the attitude of American sanitary engineers towards water analyses. This altered viewpoint is exceedingly important, although it is somewhat difficult to put into words. In the first place, there has been a shifting of the emphasis from the chemical to the bacteriological tests, as being more definitely indicative of the sanitary quality of the water. There has been a growing feeling that the old method of "interpreting" the chemical analysis was too speculative, and that the nitrogen tests were too liable to be upset by disturbing conditions to make them trustworthy as a basis of interpretation. At the same time the reliability of the bacteriological tests has failed to become fully established. In short, there has been a loss of confidence in water analyses as an index of the wholesomeness of unpurified waters. Fortunately, as a result of various sanitary reforms, prominent among which is water filtration, there has been a notable reduction of such diseases as typhoid fever.*

Throughout the United States there has been a great extension of the practice of water filtration. Water analyses have been found essential to the proper control of filter operation, but the tests useful for this purpose are quite different from those used as a basis of interpretation of the wholesomeness of unfiltered waters. In water filtration the nitrogen determinations have little or no value, but the bacteriological and microscopical tests, the chemical tests of hardness, alkalinity, and free carbonic acid, and the physical tests of color, turbidity, and odor are important and are being made throughout the country in enormous numbers.

In places where the water supply has been made reasonably safe against infection, public interest in the quality of the supply is shifting from its sanitary quality to some of its less important but more obvious characteristics. One reason for this is that filtration, while making water supplies safe, also makes them clean. The inhabitants of cities are becoming

*The average typhoid fever death-rate for the state of Massachusetts in 1920 was 2.5 per hundred thousand. The highest death-rate in any city was 10.7, and only five cities had death-rates about 5 per hundred thousand.

accustomed to clean water, water which has little color and a brilliancy not found at all times in unfiltered surface waters. Many communities also are supplied with ground waters, which are clear, colorless, brilliant, and odorless, except in some places where there is trouble from iron or manganese. Without doubt the popular standard of purity of public water supplies is steadily rising. Algæ growths continue to cause complaint in many places on account of the odors which they produce. It is the writer's opinion that in Massachusetts, where the safety of the public water supplies is well assured, the people will not and ought not to be content until the water furnished is practically free from odor and vegetable stain and is as good in appearance as the water in the cities, once supplied with muddy water, which are now enjoying the benefits of filtration.

There is one other property of water which is attracting increasing attention, — namely, its corrosiveness. Plumbing is far more common than a generation ago, the amount of money spent annually in the United States for plumbing supplies running into millions of dollars; the materials used for piping have undergone changes, lead being replaced by iron and steel, and brass pipes being much used; hot-water heating has become more common; plumbing repair costs have increased; the use of meters has shown that the leakage of water is greater in the houses than in the street mains. The use of ground water and mechanically filtered waters, which in Massachusetts are more corrosive than ordinary surface waters, has increased the problem of corrosion. All of these things are tending to give the corrosion factor a greater prominence than it has ever had before. In the future it must be reckoned with as one of the major elements of the water-supply problem. It must be attacked from both sides, — that of the quality of the water supplied and that of the character of the materials used for conveying and using water.

In making a rating of the qualities of the water supplies of Massachusetts, then, we have four major items to consider, — namely (1) sanitary quality, (2) general attractiveness, (3) mineral constituents, and (4) corrosiveness.

Rating of Sanitary Quality.

The "sanitary quality" of a water supply is the term by which we describe its likelihood of conveying disease germs from some source of pollution to the water consumers. It is fundamentally a bacteriological question. If bacteriological tests were not so imperfect, it would be possible to base a sanitary rating of the water on these tests; but inasmuch as the infection of a water supply is rarely constant but occurs suddenly and usually without warning, no rating, especially if based on analyses alone, can be regarded as perfect. It may be worth while to consider some of the underlying principles as we now view them.

The presence of disease-producing organisms in water cannot be reliably determined by analysis. Certain relatively harmless bacteria of fecal origin, such as *B. coli* and *B. Welchii*, can be detected in water, but there are no ready methods of accurately determining the number present, and there are no methods for distinquishing between those derived from human excreta and those derived from animals or birds. Nevertheless, these tests, although somewhat uncertain bacteriologically and unsatisfactory statistically, are of much use as an index of the likelihood of infection. The presence of bacteria that will grow on culture media at the temperature of the human body is another index, and the presence of bacteria that will grow at room temperature is still another, but is less definite as an indication of danger. All of these bacteriological tests, to be of value, must be made at frequent intervals, often enough to cause the analytical results to reflect the natural changes in the quality of the water. In local laboratories, such as exist at all large filter plants and in some cities where the water is not filtered, these frequent tests can be made at a reasonable and justifiable cost, but obviously it is an expensive method of control if conducted continuously on a state-wide basis.

The bacilli of typhoid fever and other known water-borne diseases do not multiply in water but decrease at a nearly constant percentage rate from day to day, the rate varying with temperature and light, with the substances present in the water, and doubtless with factors still unknown. The rate of decrease is usually lower in winter than in summer. Under average conditions it may be considered as about 20 per cent. per day. At this rate, after one day's storage 80 per cent. of the bacilli would be left; after two days' storage, 80 per cent. of 80 per cent., or 64 per cent.; after one week, 21 per cent.; and after one month, 0.12 per cent.; etc. There is no way of determining by analysis this "age of pollution." Many will remember the words which Dr. Drown so commonly used, "The state of change is the state of danger." By comparing the four tests for nitrogen and observing whether a considerable proportion of it was present in the intermediate stages known as free ammonia or nitrite, he made inference as to whether the organic matter was in a state of change, — that is, whether the pollution was probably recent. Such inferences are often sound, and the methods are as good to-day as they ever were, but they are interfered with to a considerable extent by growths of algæ in surface waters, and by bacterial reduction of nitrate in ground water, so that taken by themselves they are not very trustworthy. As a matter of fact, the probable age of pollution in surface waters can in most cases be determined quite as well by inspection and by hydraulic methods, unless the pollution accidentally occurs in the reservoir itself or near the intake, as might happen in the case of boating, fishing, ice-cutting, and the like.

The "population per square mile" on a watershed is a useful index of the opportunities of infection, and may be regarded as the basic measure of the danger at the source. This must be multiplied by one or more

factors of safety, which depend partly upon natural and partly upon artificial conditions. The natural conditions include character of the soil, the slopes of the watershed, the size and shape of the reservoirs, the nominal storage period, and other minor influences which together control the time required for pollution to reach the consumers. The nature of the soil is a matter of great importance, — sandy soils, and even gravelly soils, affording much higher factors of safety than tight, clay soils. Storage reservoirs which have a straight axis are less effective in their sanitary protection than those which are curved, as there is more danger that winds may drive the water quickly from the inlet to the outlet without mixing, and thus reduce the age of the water. In a curved reservoir, or one which has irregular shores or promontories between the inlet and the outlet, as at Fresh Pond, Cambridge, there is less chance that the incoming water will pass to the outlet unmixed with the water already in the reservoir. Mixture results in the wide dispersion of any pollution, as well as longer storage. The artificial conditions include methods used by the people living on the watershed for disposing of fecal matter. For equal populations, towns and villages, if they are sewered into the streams used as water supplies are more dangerous than isolated farms, but they are less dangerous if they are sewered and the sewage diverted from the watershed. An uninhabited watershed ought not to be considered as wholly without danger, because of the chance that people may wander over it in the course of boating, fishing, ice-cutting, hunting, automobiling, and so on.

The writer and his students have attempted to express these various factors in figures, but the problem is so complicated and the necessary data so difficult to secure that none of the results are worth publication. It is necessary to fall back upon the exercise of judgment in each particular case, striving always to reduce the chances of pollution and increasing all possible factors of safety. In spite of difficulties in weighting and combining the various factors into a mathematical sanitary index, it is important to recognize that long experience has proved that the natural factors of safety are of real and substantial value.

It is interesting to compare the index method of studying the potential danger of infection of a water supply with that used by Stearns and Drown some years ago. As a check on "persons per square mile" they used the "excess of chlorine" above the normal of the region. They found that each person per square mile increased the chlorine by 0.005 part per million (State Sanitation, II, p. 139). They could not very well use the nitrogen determinations to obtain the time factor of safety because of the interference of the algæ growths and for other reasons, but it is evident that in their discussion of the analyses they did make a mental allowance for a time factor based on the nitrogen determinations, calling it, however, the "state of change," which meant a state of danger.

There is another factor which enters into the problem of safety from infection, the factor of *chance*. It is not possible to compute with a satis-

factory degree of precision the chance of infection of a water supply. It is not the average condition which produces an epidemic; it is some exceptional combination of conditions. The frequency with which these may occur is not subject to computation. It may be asserted, however, that water supplies which are uniform in quality as shown by analyses are safer than those which show wide fluctuations from time to time, just as reservoirs which are always full are safer than those which are sometimes nearly empty, and just as people who live a regular life are less subject to untimely death than those who are irregular in their habits. It is possible to study the variations in the quality of water by applying the laws of probability to the results of analyses when these have been made with regularity over a long period of time. Variations in color, chlorine, organic matter, nitrogen as free ammonia, and especially in bacteria and *B. coli* give opportunities for studying the fluctuations in quality, which may be due to increased discharge of water from swamps, increased washing of the soil, sudden movements of water across a reservoir, effects of unusual pollution, or other causes. In the same way variations in the quantity of water stored in a reservoir and even variations in rainfall are an index of unsafe conditions. It would be well to adopt as a guiding principle a paraphrase of Dr. Drown's dictum, and say that "*a state of irregularity is a state of danger.*"

These same principles may be applied to surface water supplies protected by filtration. The potential danger of a filtered water depends upon the density of population on the watershed, multiplied by a factor of safety supplied by the filter. The value of this factor may be taken as the per cent. which the number of bacteria in the filtered water is of the number present before filtration. Ordinarily this will not exceed 1 or 2 per cent. under average conditions, and will often be much less than 1 per cent. But here again the element of chance comes in. Some filters work steadily and give results which do not vary much in efficiency from day to day; other filters, because of being ill adapted to the service, poorly designed, or poorly operated, or, perhaps, because of being outgrown, give results which vary considerably from day to day or even from hour to hour. Here also one may say *the state of irregularity is the state of danger.* Large filters are usually more uniform in their performance than small filters, just as large storage reservoirs are usually more uniform in the quality of their water than small reservoirs. Hence with small supplies the population factor is of greater importance than with large supplies. Superintendents of small water works need to protect the original sources of their water supplies with especial care.

As to chlorination, it may be said that the process furnishes a high factor of safety under average conditions, but that the factor of irregularity is a more serious one than in the case of filtration. If chlorination fails, as it sometimes does for short periods, the factor of safety is reduced to zero. If this process is to be depended upon, this serious element of

irregularity must be overcome. Of course, the combination of filtration and chlorination multiplies safety, but the policy of cheapening filtration, utilizing it for clarification only and depending upon chlorination for bacterial purification, is one that is attended with great danger, and ought not to be followed.

Unfortunately, the factor of safety of water-purification works of any kind involves the human element, which is somewhat erratic, and especially liable to be so in small plants where the attendance is not constant and where the operation is necessarily left to persons who are not expert in the special field of water purification.

Massachusetts with her many small supplies has very properly placed the chief emphasis on the protection of the original sources of the water, has emphasized sanitary inspections, has favored the acquisition of land for protecting water supplies, and has been opposed to such dangerous practices as boating, fishing, and ice-cutting on reservoirs. As the state becomes more populated, as the cities become larger, it will doubtless be necessary to add to the natural factors of safety those which are obtained by various methods of purification. In some cases these have already been adopted. Massachusetts is fortunate in having favorable soil conditions and storage facilities for water-supply purposes.

Attractiveness.

The word "potability" was first used to describe the "drinkable" characteristics of water, and had reference to certain very obvious qualities. Water which is lukewarm is not drinkable; neither is water which tastes or smells bad or which is offensive to the sight. Sea water is not potable. Popularly speaking, an infected water, however, may be potable, — as, for example, an infected well water. In recent years the term "potability" has been widened to include the sanitary quality, the safety, the wholesomeness, in fact, all of the qualities of a public water supply, and the result has been that a perfectly good word has gone out of current use in America. Now, when we wish to describe the potability of water, we speak of its attractiveness, its "esthetic" qualities. When people say, as they so often do, that "We have the best water in the state," or "We have the best well in the village," it is attractiveness which they have in mind, not safety from infection. When the time comes that all public water supplies are reasonably safe we may be able to restore the word "potability" to current use.

There are several properties which combine to make up this quality of attractiveness:

1. Color, measured by comparison with standards.
2. Clearness, measured by the turbidity test.
3. Brilliancy, for which there is no accepted test.
4. Odor, due in great measure to microscropic organisms.

5. Taste, due largely to dissolved organic or mineral matter.
6. Aëration.
7. Temperature.
8. Esthetic surroundings of the source.

Of these properties, color, turbidity, aëration, and temperature can be measured with accuracy. Taste and odor can be described in simple, approximate terms, but cannot be measured accurately. Brilliancy is a quality which we may some day learn how to measure. It is due apparently to an absence of colloidal clay and finely divided organic matter. It is probable that by the further development of the Tyndall ray we shall be able to measure, as well as indicate, the amount of these colloidal substances. Every one knows how dust particles in the air over a hayloft can be detected by the ray of sunlight which enters through a crack in the barn. That is the principle of the Tyndall ray, and also that of the ultramicroscope. Brilliancy is a sort of extension of the idea of clearness. Some waters are clear, — that is, they have no turbidity, but they are not brilliantly clear; they do not sparkle. As Houston says, filtered waters ought to have a "clean, polished look." Some colored waters are brilliant, just as tea is brilliant, or that ancient liquor known as beer. Therefore not all colloidal matter interferes with this quality of brilliancy.

The sparkling of water is due to brilliancy coupled with aëration. Very finely divided bubbles of air emerging from solution reflect the light and make the water sparkle. Spring water, being cold, contains more dissolved air than it can hold in solution after it has been warmed. Consequently these gases come out of solution, appear as minute bubbles which sparkle, and then coalesce to form larger bubbles visible to the eye, and perhaps collect on the sides of the glass. We do not reach perfection in water purification until we produce water like the "sparkling spring." Artificial aëration will make a brilliant water sparkle.

The various qualities which combine to make up the attractiveness of water are of immediate and daily concern to the consumers. Experience has shown that some people demand a water which closely approaches the ideal of attractiveness; others make no remark at slight departures from the ideal, but complain if the water is dirty or too highly colored or has an odor. A point may be reached, however, when, because of excessive color or turbidity or because of bad odors, nearly all persons object to the quality of the water, — that is, the water becomes non-acceptable, non-potable. There are also persons who have a natural repugnance to drinking water from a polluted source, even though assured that the water is safe and even though it is delivered in a fairly satisfactory state. The esthetic surroundings of a water supply are elements of real value.

It is possible to set fairly definite standards for the obvious qualities of color, turbidity, and odor. It might even be possible to combine them into an index of attractiveness and use it for comparing different water supplies. Such comparisons are more curious than useful, for each

community must draw its water supply from naturally restricted sources and must also look well to the cost of its water service. Nevertheless, it is important that every supply be made attractive to the consumers, and in the long run the consumers are the best judges. It is not for the engineers and chemists to set the standards of attractiveness, but to register the opinion of the consumers, bearing in mind that communities differ in their ideas just as people differ.

While the ideal color is zero, waters which have colors less than 10 are nearly always regarded as practically colorless. Colors between 10 and 20 are acceptable in New England provided that the waters are not also turbid. Dirt and microscopic organisms in water accentuate color. When the color exceeds 40 or 50, or even when it exceeds 20 with suspended matter present, the water is not satisfactory for drinking, as it looks dirty in a glass or in a porcelain washbasin or bathtub.

New England waters are seldom as turbid as those of the South and Middle West, where the soil contains much clay. The glacial drift which covered the northern part of the country did much to guarantee attractive water supplies. Such turbidity as is found is usually of such a character that it quickly settles on standing and forms a sediment. It is difficult to measure this sediment by the standard silica scale, and the analysts have taken recourse to descriptive words such as slight, distinct, heavy, etc. As a rule, according to Mr. H. W. Clark, these terms correspond to weights of sediment about as follows:

Very slight	0– 2 parts per million.
Slight	3– 10 parts per million.
Decided	11– 50 parts per million.
Considerable	51–100 parts per million.
Heavy	101 parts per million.

Turbidity may be due to microscopic organisms, and this has also been described in words, such as very slight, slight, distinct, decided, etc. Hardly one sample in twenty has turbidity enough to enable it to be expressed on the numerical scale.

The turbidity and sediment in water is subject to seasonal fluctuations and is influenced by the erratic occurrence of microscopic organisms and soil washings after heavy rains. In classifying the water supplies of the state according to turbidity, the best method appears to be to record the per cent. of time during which certain conditions prevail.

No attempt has ever been made to measure brilliancy. This is a quality which needs to be studied. Waters which contain both color and turbidity are dull or "murky."

Nearly all ground waters are brilliant unless they contain iron or manganese. Very few of the surface waters of New England are constantly brilliant, because of microscopic organisms or other organic matter, but they can be made so by filtration. Some waters lose their brilliancy by picking up iron rust from the distribution pipes. A water may have a

color above 20 and yet be brilliant. Brilliancy is a quality much desired and highly prized. A brilliant water of color 30 is liked better than a dull water of color 15. It is not possible to classify Massachusetts waters according to brilliancy in a reliable way on the basis of present data.

Growths of microscopic organisms are characteristic of the surface water supplies of New England. They occur intermittently, and vary greatly in different reservoirs. Some of them merely make the water dull or murky; others give rise to odors characterized as grassy, aromatic, fishy, etc. Decaying organic matter, including decaying organisms, give moldy odors. Even the harmless organic matter which produces color gives to water a vegetable or swampy odor. All of these odors vary in intensity as much as they vary in character.

It would be possible to classify the waters of the state according to the number of organisms present, but as there are many species of organisms it would require an elaborate study. The organisms are fragile and are often destroyed during the transportation of the samples, so that the results of analyses are not always true. Furthermore, the State Department of Public Health has never adopted the standard unit system of keeping records, the most satisfactory method yet devised. Hence the published results have only a general value for purposes of comparison. It will therefore be more practical to classify the water supplies according to the odor test, even though the odors are subject to change during the transportation of samples and also subject to a personal equation, the sensitiveness of the sense of smell of the water analyst. As a rule the algæ odors as observed by the analyst are less pronounced than those observed by the consumer taking a glass of water directly from the tap, — just as the flavor of strawberries purchased in the city is not as sharp and delicious as when the berries are first picked. Moldy odors, on the other hand, become intensified when water stands in a closed bottle.

The most useful basis for comparison seems to be the per cent. of time during which the water supplies have possessed odors of different degrees of intensity. This assumes that all odors are objectionable, whatever their character; that " very faint " and " faint " odors are noticeable; and that " distinct " and " decided " odors are objectionable. Thus by putting together the weekly odor records kept in the laboratory of the Metropolitan Water Works during the years 1905 to 1920, and dividing them into five classes, A, B, C, D, and E, we get the following results, which have been computed from data furnished by Mr. Charles E. Livermore.

ODOR TESTS, METROPOLITAN WATER WORKS, 1905–1920.

(Figures indicate percent of lime.)

	A. Practically no odor.	B. Odor too faint to attract attention.	C. Odor noticeable but not enough to cause complaint.	D. Odor strong enough to cause some complaint.	E. Odor strong enough to cause general complaint.
Wachusett Reservoir	4.4	85.8	5.8	3.2	0.8
Sudbury Reservoir	1.5	73.3	15.2	9.0	1.0
Framingham Reservoir, No. 2	1.0	80.7	10.0	8.1	0.2
Lake Cochituate*	0.4	38.8	29.5	23.6	7.7
Chestnut Hill Reservoir	3.0	84.4	8.2	3.5	0.9
Spot Pond Reservoir	3.0	78.2	13.2	4.8	0.6
Tap, 180 Boylston Street	1.9	84.7	8.0	4.9	0.5
Tap, Ashburton Place	1.7	84.5	7.4	5.6	0.8

These figures show that in the Metropolitan District the odor of the water is strong enough to be noticeable and cause some complaint for two or three weeks each year.

MINERAL CONSTITUENTS.

The surface waters of Massachusetts are not highly mineralized. The mineral solids seldom exceed 75 parts per million. In the Berkshire district, where there are limestone deposits, the surface waters are a little harder than elsewhere. The ground waters are naturally harder than the surface waters. The hardnesses of the wells vary somewhat erratically. Wells near the coast are inclined to be hard. Household wells that are polluted are also hard.

The term "soft" may be logically applied to waters which have a hardness of less than 12 parts per million, this being about the limit of the solubility of normal calcium carbonate. The terms for the other classes have local application only. Popularly speaking, hardness is a relative term. All Massachusetts waters would seem soft to people acccustomed to the hard waters of the Middle West.

Iron and manganese are elements which give rise to more or less trouble in our Massachusetts water supplies. These troubles are confined chiefly to ground waters.

CORROSION.

According to modern theory, the corrosion of metals is incited by the presence of hydrogen ions in water. Ions carry electrical charges, hence the phenomena of corrosion are properly regarded as electrical. When two different metals in contact, or even without being in contact, are immersed in water which, because of the presence of electrolytes, conducts electricity, galvanic corrosion will occur. If a current of electricity is passed through the system, corrosion will be accentuated. The actual

* Held as a reserve supply and seldom used.

rusting of iron is brought about by the oxygen dissolved in the water, and it may be said that most water supplies are fully charged with dissolved oxygen.

Until within a few years it was not regarded as practicable to measure the amount of the hydrogen ion as a routine laboratory procedure. It

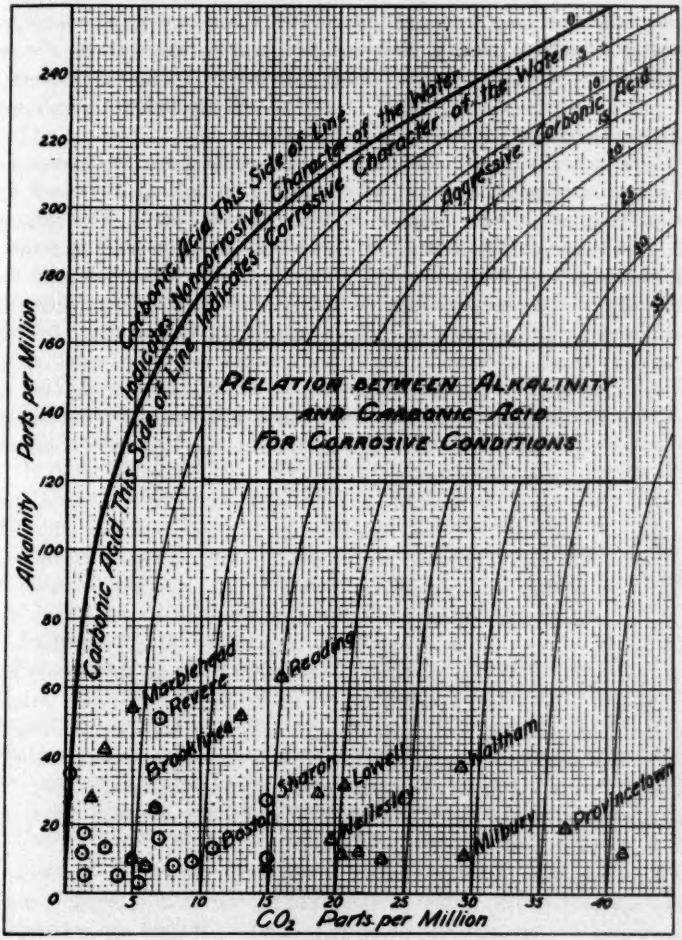


FIG. 1.

is now possible to do so, and the test is easily made. A hydrogen ion survey ought to be made of all of the water supplies of the state and extended through an entire year in order to obtain the effect of seasonal changes.

But even without such a survey it is possible to compare the relative corrosive powers of waters on the basis of certain chemical tests which

have already been made, — namely, carbonic acid, alkalinity, color and chlorine. The presence of dissolved free carbonic acid means that hydrogen ions are present. The presence of chlorine (actually chlorides) means that the water will conduct electricity and that galvanic action may occur. Alkalinity (due to calcium or magnesium carbonates and hence making up part of the hardness) retards corrosion. Coloring matter means organic acids and more hydrogen ions. Hence soft waters which contain free carbonic acid or coloring matter are corrosive. Waters near the sea, or well waters that are polluted, are corrosive because of the presence of chlorides and accompanying salts. Hard waters are less corrosive, even though carbonic acid and chlorides are present.

The free carbonic acid in water is subject to great variations. In surface waters, exposed as they are to the air, it seldom exceeds 2 to 5 parts per million, as the water is delivered to the city. The stagnant strata of water near the bottom of a reservoir may contain ten times as much as this. Well waters usually contain much more carbonic acid than surface waters, and the amount is subject to most erratic changes, so that only by making a large number of tests can the average amount be fairly determined. Such tests have the disadvantage that for exact results the operations must be performed on samples at the time of collection and not on samples sent to the laboratory. Many of the surface waters have their carbonic acid reduced to zero during the summer by reason of growth of algæ.

Recent studies have given a basis for estimating the combined corrosive effect of carbonic acid and hardness, — the one corrosive, the other protective. For any given amount of carbonic acid there is a corresponding hardness which will furnish protection. This relation is shown by Fig. 1. If for any given hardness the carbonic acid is more than that shown by the curve, the excess may be termed " aggressive " and the water will be corrosive. In some sections of the country where the waters have a hardness of one or two hundred parts per million there is very often no aggressive carbonic acid, but with the soft waters of New England nearly all of the carbonic acid is aggressive. To make an appraisal of the water supplies of the state from the standpoint of corrosion is not easy. The basis of such a comparison is obtained by using the chemical determinations of carbonic acid, chlorine, alkalinity, and hardness.

Our knowledge of these matters is not yet sufficient to enable us to classify adequately the waters of the state on the basis of their corrosive power, but a few generalizations may be made. Waters are corrosive in proportion to their aggressive carbonic acid and in proportion to the chlorides present. The hard surface waters of the western part of the state are low in chlorine and are but slightly corrosive. The soft surface waters of the middle and eastern portions of the state are slightly corrosive during the greater part of the year because of the presence of small amounts of aggressive carbonic acid. The well waters of the state, although gener-

ally harder than the surface waters, are more corrosive because of the presence of more aggressive carbonic acid. Pollution increases the aggressive carbonic acid. Ground waters taken from infiltration galleries near rivers or wells located in swampy places are especially liable to contain aggressive carbonic acid. Alum-treated waters contain more aggressive carbonic acid than before treatment, as the alkalinity is reduced and the free carbonic acid increased. Water supplies near the coast and polluted waters have their corrosive power increased by reason of higher chlorine contents. The next few years ought to show a marked increase in our knowledge of this subject.

The subject of lead poisoning is connected with that of corrosion. Much attention has been given to it in Massachusetts, especially in the early days. There is less lead poisoning from public water supplies now than formerly, largely beeause less lead pipe is used in house plumbing; but the matter is one that should not be allowed to drop out of sight. In some cities it is still important, and in a few places it is of serious import. In Providence the water is artificially hardened in order to reduce the aggressive carbonic acid. This practice will some day become more common than it now is.

Classification of Massachusetts Waters.

Having considered the various elements involved in a rating of the quality of water from the standpoint of the consumer, we may now turn to the water supplies themselves and set forth some of the results for the purpose of comparison, by means of tables and diagrams. These data were compiled by Miss Bertha M. Brown, C. P. H., recently a student in the School of Public Health of Harvard University and the Massachusetts Institute of Technology.

For the sake of simplicity the supplies were divided into five classes, A, B, C, D, and E (represented by the colors: blue, green, yellow, orange, and red on the maps*), for each of the analytical tests considered. These classes were intended to represent the qualities of the water from good to bad, — classes A and B being satisfactory, classes D and E being unsatisfactory, and class C being intermediate between the two.

The analytical values used in making this classification were as follows:

Significance of Colors Used on Classification Maps.

Class		Turbidity or Sediment.	Odor.	Color.	Parts per Million		
					Hardness.	Iron.	Chlorine
A	Blue	None	None	0–10	0– 5	0.00–0.10	0– 5
B	Green	Very slight	Very faint	11–20	6–12	0.11–0.40	6–10
C	Yellow	Slight	Faint	21–40	13–25	0.41–1.00	11–15
D	Orange	Distinct	Distinct	41–60	26–50	1.01–2.00	6–20
E	Red	Decided	Decided	61	51	2.01	1–21

* These maps were displayed at the meeting, but are not here reproduced.

On the maps the circles indicate surface waters, the triangles ground waters. These are sometimes divided into proportional parts, shown in different colors and corresponding to the percentage of time during which the different conditions prevail during the year. The intention has been to show the quality of the water as delivered to the consumers, and the circles and triangles are placed over the city or town supplied, regardless of the location of the source. The data used in preparing the maps are given in tabular form, beyond.

No attempt will be made here to compare one supply with another, but each superintendent of water works will doubtless be interested to see where his supply stands in the list. Certain general explanations of the tables and maps, however, should be made.

No comparisons of sanitary quality are given, as no acceptable index has been found suitable for the purpose. Furthermore, the various factors essential to such an index are not known in so many cases that computations are practically impossible. The sanitary quality of each water supply must still be regarded as a matter of estimate and judgment, based on all of the local conditions.

In the case of color, hardness, chlorine, and iron, the averages of the monthly analyses were used. As a rule, the figures for chlorine and hardness vary but little from month to month or from year to year. The color of surface waters varies seasonally and the variations are considerable. Thus one of the supplies (Cambridge) included in class C on the basis of its average color would be placed in the other classes during a certain part of the time, as follows: A, 0 per cent.; B, 5 per cent.; C, 90 per cent.; D, 5 per cent.; E, 0 per cent.

The data show that practically all of the unfiltered surface supplies are unsatisfactory at times by reason of odor, turbidity, and sediment, and that many of them are in the unsatisfactory color class, while most of the ground waters are satisfactory in all these respects. These qualities which go to make up the attractiveness are controllable.

Variations in Quality.

The writer has taken pains to emphasize the importance of regularity in the quality of a water supply. A water which always has a color of 15 is liked by the consumers better than one which has an average color of 15 with variations from 5 to 30. Consumers are apt to judge a water supply not by its best but by its worst condition. To study all of the water supplies of the state from the standpoint of regularity would be interesting and would go a long way in determining the relative safety of the different supplies. The writer wishes to urge each water-works superintendent to study the analyses of his supply from this point of view. Two examples may be given to illustrate the method of procedure. The first is a comparison between Wachusett Reservoir, which represents a water

of uniform condition, and Worcester, which represents a water of variable condition, the test for chlorine being used. The second is a comparison between the color of the raw and filtered water at the Springfield filter.

In Wachusett Reservoir during the years 1903–1920 the median amount of chlorine present was 2.72 parts per million, but during one tenth of the time this figure was exceeded 20 per cent., and during a hundredth of the time by 37 per cent. In Tatnuck Brook Reservoir of the Worcester supply the median value was 1.49 parts per million, but during one tenth of the time this value was exceeded by 50 per cent., and during a hundredth of the time by 60 per cent. This and other similar studies show how much more uniform in quality the larger supplies are than the smaller supplies.

At Springfield during the year 1912 the raw Little River water had a median color of 31, but one tenth of the samples had colors of less than 20 and another 10 per cent. had colors higher than 55, the extreme colors being 16 and 95. In the case of the filtered waters, however, the median color was 15. One tenth of the samples had colors less than 13, and one tenth more than 18, the extremes being 10 and 30. In other words, the filtered water was not only lower but more uniform in color than the raw water.

Certain constituents of surface waters, as, for example, chlorine, hardness, and other mineral substances, vary but little from month to month, and frequent analyses are not necessary. But color, odor, microscopic organisms, and bacteria are constantly varying, and more frequent sampling is needed if these changes are to be followed.

The Question of Filtration.

Comparatively few of the surface-water supplies of Massachusetts are filtered. Of the large supplies there are only three. The Lawrence filter was built in 1892 as a protection against the gross pollution which the Merrimac River receives. In spite of the fact that this water can be made safe by this process supplemented by chlorination, the supply is not favorably regarded by the citizens, for sentimental reasons. They say that they do not wish to drink the sewage of Lowell, however thoroughly purified. The Springfield filter was built in 1909, largely to improve the attractiveness of the Little River water, but also to secure an added factor of safety against pollution. By means of coagulation with a small amount of alum and slow sand filtration the color has been kept at a nearly uniform figure and the water has been made brilliant. It has a high factor of regularity. The Lowell filter was built in 1915 and the Brookline filter in 1917 to remove iron and manganese from ground waters. The city of Cambridge has a filter under construction. There are several smaller filters in the state built to remove iron from ground waters or to clarify

surface waters. The filters in Masachusetts on January 1, 1921, were as follows:

FILTERS IN MASSACHUSETTS ON JANUARY 1, 1921.

City or Town.	Date of Installation.	Type of Filter.
Athol	1887	Mechanical.
Cohasset	1914	"
Reading	1896	"
Scituate	1913	"
Brookline	1917	Sand filters for removal of iron.
Lowell	1915	"
Marblehead	1909	"
Middleborough	1915	"
Athol	1912	Slow sand filters for filtration of surface waters.
Lawrence (2)	1892, 1893	"
Milford	1895	"
Northfield (East)	1915	"
Norwood	1913	"
Southbridge	1908	"
Springfield (Ludlow)	1906	"
Springfield (Little River)	1909	"
West Springfield	1907	"
Attleborough	1908	Filters to which surface water is applied to supplement ground sources.
Bedford	1909	"
Greenfield	1913	"
Hingham	1903	"
Leicester (Cherry Valley)	1912	"
Newburyport (2)	1908	"
Salisbury	1915	"

In addition to the above there is a slow sand filter at the Bridgewater State Farm, and the Metropolitan Water and Sewerage Board maintain open sand filters for filtration of brook waters entering Lake Cochituate in Natick, Sudbury Reservoir in Marlborough, and Wachusett Reservoir in Sterling. There are also certain experimental filters not listed above.

The question, "Why are there not more filters in Massachusetts?" is one that is asked outside of the state more than within the state. As a matter of fact, the water supplies of Massachusetts taken as a whole are well safeguarded and reasonably satisfactory to the consumers. The very low typhoid fever death-rate of the state has already been referred to. Yet, looking at the data for color, turbidity, sediment, and odor, it will be seen that very few of the surface waters are attractive at all seasons of the year. In almost every case there are some weeks or months in the year when the color is too high, when the water is not clear, or when, on account of growths of microscopic organisms, the water has an unpleasant odor. Even the water supplied to the Boston Metropolitan District is no exception, as microscopic organisms appear in large numbers in Wachusett Reservoir and the other reservoirs every few years. Lake Cochituate water in recent years has been notably unsatisfactory. These occasional unpleasant conditions cause only passing comment by the

people, but the fact can not be ignored that standards of quality are rising. With the supplies of most of the large cities of the country made brilliant by filtration, the supplies of Greater Boston will before long suffer by comparison. For many years, before the days of filtration, the water supplies of New England were of much better quality than those of the South and Middle West, but with the very rapid application of filtration to these naturally muddy waters the tables are being turned and the New England supplies, because of their color, sediment, turbidity, and occasional growths of odor-producing organisms, are coming to be of lower standard of attractiveness than the others. These comparisons are more obvious to travelers than to persons who reside continually in one place and become accustomed to their own water supply.

It must not be forgotten also that while the surface water supplies of Massachusetts are well safeguarded against constant pollution, any unfiltered supply is subject to accidental contamination. Heavy rains may suddenly wash polluting substances into the streams. The "turnover" of a reservoir, because of the disturbance of thermal stratification, may carry deposits from the bottom to the supply pipes of the city. There may be accidental infection resulting from the practices of boating, fishing, and ice-cutting. Storage in large reservoirs gives a high average factor of safety but may be subject to such irregularity that the chance of danger is one which should not be ignored. Almost every year, especially in the early spring, some city of the state suffers from the sudden occurrences of a mild type of dysentery, which is so general in its distribution that the public water supply would seem to be the only possible cause. These mild outbreaks seldom result in deaths, and the cases are not even reported. They come to the attention of the health officers informally, often through the press. They are usually of such short duration that by the time the epidemiologist and the sanitary engineer take up the study the bad conditions have passed. Whether these dysentery outbreaks have been caused by water and, if so, whether they have been due to such an organism as *B. Welchii*, whether to a recent infection, or to the accumulated sediment on reservoir bottoms is not known, but, if due to water, filtration will protect a community from them, provided the filtered water is not stored in an open reservoir.

In my opinion, the time is not far distant when the people will demand the filtration of all surface water supplies, and New England water-works superintendents will do well to keep this possibility in mind.

If filtration is to become general, the type of filter is a matter of importance and one which should already be receiving attention. Unfortunately, the satisfactory removal of color from soft water is one of the most difficult problems of water purification. The exact nature of the reaction between alum and coloring matter is not yet known. Sanitary chemists used to say that all of the aluminum sulphate was changed to hydrate and that none of it went through the filter. Mr. Hiram F. Mills

stoutly denied that this was so, — although he could give no reason for it, — and we are now coming to believe that he was right. The use of alum with short periods of coagulation and mechanical filtration of the ordinary type is, in my opinion, inappropriate to our soft-colored Massachusetts surface waters. We must find some modification of the process which will be better, and I think this can be found. The corrosion problem in our state is serious already and must not be made more so by inappropriate chemical treatment. This is no place to enter upon a discussion of this problem, but it is one for the State Department of Public Health and for this Association to study in all seriousness.

Use of Water Analyses.

Finally, the writer wishes to urge the water-works superintendents of New England to give greater attention to the analyses of the water supplies under their charge. Analyses are useless unless used. The state sanitary engineers and chemists use them constantly in the course of their supervision, but even this tends to become a perfunctory proceeding unless the superintendents show a coöperative interest. In 1917 the Health Commissioner of Massachusetts sent out a questionnaire relating to water analyses. In reply, thirty-two superintendents said they made no use of the analyses sent out by the State Department of Health; 19 said that they kept them on file; 18 said that they published them in their annual report; 23 said that they occasionally showed them to inquiring consumers; 28 said that they used them to compare present with past conditions; and only four said that they regarded them as having any important use. The following extracts from the replies illustrate the different points of view:

"I have not read a copy of the analyses for a year or more."
"About once a year some one asks to see them."
"It is good to be able to say we have the water frequently analysed."
"Enables us to give intelligent answers to inquiries regarding water supplies."
"If any water-taker growls about the water, I just show him the last report, and that seems to settle the matter."
"Very valuable."
"No use, except to know that the State Department is keeping tabs on us."
"Value for reference and comparison year by year."
"To show to inquiring strangers."
"To show to federal inspectors."
"Have relied upon analyses for record of purity."
"Only to show to disgruntled water-takers."
"To watch the need of cleaning reservoir."
"I regard them as of the highest value."
"To determine whether there is unusual pollution."
"Analyses make us feel sure that the water is all right."

"To determine increase in pollution."
"Guidance in protecting the supply."
"To look out for turbidity and nitrates."
"To tell whether our suction pipe is tight."
"Essential to watch chlorine."
"The fact that the State Department of Health makes analyses seems to be sufficient to satisfy our consumers that there is no danger."
"Requested by doctors in interest of patients."

All of the consulting engineers who replied to the questionnaire were emphatic in their appreciation of the analytical work being done.

The results of this canvass must be regarded as a serious reflection on the present system of analysis and also on the interest which the local authorities take in the attractiveness of the water which they supply. They show an over-confidence in state supervision. Since the active work of Mills, Stearns, Drown, and Sedgwick, a new generation of superintendents has come forward, and it is because the men of the present day need to have their interest aroused that the writer has brought together various facts and ideas which, for the most part, are not new and which are already well known to many of the members of this Association. It is hoped also that the State Department of Public Health will revise its present system in order to bring it into line with the analytical standards generally adopted elsewhere in the United States and in order to make the data of greater practical value to the water superintendents.

TABLE 1

List of Cities and Towns in Massachusetts which have Public Water Supplies, January 1, 1920.

SURFACE WATER

Abington
Acushnet
Agawam
Amherst
Andover
Arlington (Metropolitan)
Ashburnham
Ashfield
Athol
Belmont (Metropolitan)
Beverly
Blackstone
Blandford
Boston (Metropolitan)
Braintree
Brockton
Cambridge
Chelsea (Metropolitan)
Cheshire
Chester
Clinton
Colrain
Concord
Dalton
Danvers
East Longmeadow
Egremont
Erving
Everett (Metropolitan)
Fall River
Falmouth
Fitchburg
Gloucester
Great Barrington
Groveland
Hadley
Hatfield
Haverhill
Hinsdale
Holbrook
Holden
Holyoke
Hudson
Ipswich
Lancaster
Lawrence
Lee
Lenox
Leominster
Lexington (Metropolitan)
Lincoln
Longmeadow
Ludlow
Lynn
Malden (Metropolitan)
Marlborough
Maynard
Medford (Metropolitan)
Melrose (Metropolitan)
Middleton
Milton (Metropolitan)
Montague
Monterey
Nahant (Metropolitan)
New Bedford
North Andover
North Brookfield
Northampton
Northborough
Peabody
Pittsfield
Plymouth
Quincy (Metropolitan)
Randolph
Revere (Metropolitan)
Rockland
Rockport
Russell
Rutland
Salem
Saugus
Shelburne
Somerville (Metropolitan)
Southbridge
Spencer
Springfield
Stockbridge
Stoneham (Metropolitan)
Sunderland
Swampscott (Metropolitan)
Taunton
Wakefield
Watertown (Metropolitan)
Wayland
West Bridgewater
West Springfield
Westfield
Weymouth
Whitman
Williamsburg
Winchester
Winthrop (Metropolitan)
Worcester

GROUND WATER

Acton
Amesbury
Ashland
Attleborough
Avon
Ayer
Barnstable
Bedford
Billerica
Bridgewater
Brookline
Canton
Chelmsford (Centre & North)
Cohasset
Cummington
Dedham
Douglas
Dracut (including Collinsville
Dudley
Dunstable
Duxbury
Easthampton
Edgartown
Fairhaven
Foxborough
Franklin
Grafton
Granville
Groton
Hardwick
Holliston
Hopkinton

GROUND WATER — *Continued.*

Kingston	Needham	Tisbury
Littleton	Newton	Uxbridge
Lowell	North Attleborough	Walpole
Mansfield	Northbridge	Waltham
Marion	Norton	Ware
Marshfield	Oak Bluffs	Webster
Mattapoisett	Oxford	Wellesley
Medfield	Pepperell	West Brookfield
Medway	Plainville	West Stockbridge
Merrimac	Provincetown	Westborough
Methuen	Reading	Westford
Middleborough	Salisbury	Weston
Millbury	Sharon	Westwood*
Millis	Sheffield	Winchendon
Monson	Shirley	Woburn
Natick	Shrewsbury	Wrentham

BOTH SURFACE AND GROUND WATER

Adams	Hingham	Norwood
Barre	Hopedale	Orange
Brookfield (Centre and East)	Hull	Palmer (including Bondsville)
Chicopee	Huntington	Scituate
Dartmouth	Leicester	South Hadley
Deerfield (Centre and South)	Manchester	Southampton*
East Bridgewater	Marblehead	Stoughton
Easton	Milford	Wareham (including Onset)
Framingham	Nantucket	Westhampton*
Gardner	Newburyport	Williamstown
Gill	North Adams	Worthington
Greenfield	Northfield	

TABLE 1A

CITIES AND TOWNS WHICH HAVE WATER SUPPLIES IN COMMON

Abington and Rockland	Milford and Hopedale
Brockton and Whitman	Montague and Erving
Brockton and East Bridgewater	New Bedford and Acushnet
Brockton and West Bridgewater	New Bedford and Dartmouth
Bridgewater and East Bridgewater	Randolph and Braintree
Blackstone and Woonsocket, R.I.	Randolph and Holbrook
Clinton and Lancaster	Rutland and Holden
Concord and Lincoln	Salem and Beverly
Danvers and Middleton	Springfield and East Longmeadow
Hingham and Hull	Springfield and Ludlow
Lynn and Saugus	

METROPOLITAN WATER SUPPLY

Arlington	Chelsea	Malden	Milton	Revere	Swampscott
Belmont	Everett	Medford	Nahant	Somerville	Watertown
Boston	Lexington	Melrose	Quincy	Stoneham	Winthrop

*Public supplies owned by private parties not listed in report of State Department of Public Health.

TABLE 2.

Public Water Supplies of Massachusetts.

SEDIMENT AND ODOR.

Expressed as Per Cent. of Number of Samples,
1910–1919.

City or Town.	Sediment.					Odor.				
	None.	Very Slight.	Slight.	Considerable.	High.	None.	Very Faint.	Faint.	Distinct.	Decided and Strong
Abington	28.0	54.0	16.0	2.0	0.0	2.0	24.0	50.0	22.0	2.0
Acton	74.0	16.7	9.3	0.0	0.0	98.2	1.8	0.0	0.0	0.0
Acushnet	9.3	74.0	15.5	1.2	0.0	0.0	2.5	36.0	47.8	13.7
Adams	38.0	55.7	5.0	1.3	0.0	28.9	35.0	27.8	8.3	0.0
Agawam	28.1	44.2	21.5	6.2	0.0	23.6	14.7	32.6	25.4	3.7
Amesbury	8.0	34.7	28.0	29.3	0.0	85.4	9.3	4.0	1.3	0.0
Amherst	2.8	63.3	26.6	7.3	0.0	0.9	12.8	42.2	39.5	4.6
Andover	21.2	69.0	9.8	0.0	0.0	3.3	14.7	47.5	31.2	3.3
Arlington	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Ashburnham	39.6	51.0	5.6	3.8	0.0	24.7	37.7	35.8	1.8	0.0
Ashfield	58.0	35.5	6.5	0.0	0.0	3.2	19.4	51.6	25.8	0.0
Ashland	60.7	19.7	16.1	3.5	0.0	94.7	0.0	5.3	0.0	0.0
Athol	11.3	52.2	23.9	12.6	0.0	9.5	14.9	33.3	32.6	9.7
Attleborough	93.0	1.8	1.7	3.5	0.0	94.6	1.8	1.8	1.8	0.0
Avon	81.0	16.7	0.0	2.3	0.0	100.0	0.0	0.0	0.0	0.0
Ayer	58.2	32.9	8.9	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Barnstable	92.3	7.7	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Barre	2.0	45.1	39.2	13.7	0.0	2.0	17.6	53.0	21.6	5.8
Bedford	59.0	37.2	3.8	0.0	0.0	84.7	11.5	3.8	0.0	0.0
Belmont	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Beverly	15.1	26.6	40.4	17.3	0.6	6.2	15.5	18.2	40.9	19.0
Billerica	8.2	50.0	36.0	5.8	0.0	97.7	2.3	0.0	0.0	0.2
Blackstone*	...	...	...	...	...	...	...	...	...	...
Blandford	57.3	34.6	6.1	2.0	0.0	26.6	38.8	32.6	2.0	0.0
Boston	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Braintree	59.6	36.2	4.2	0.0	0.0	87.3	4.3	6.3	2.1	0.0
Bridgewater	57.6	30.4	9.8	2.2	0.0	94.5	3.3	1.1	1.1	0.0
Brockton	3.7	59.5	32.5	4.3	0.0	11.1	46.0	31.9	11.0	0.0
Brookfield	84.4	12.8	0.0	2.8	0.0	95.8	0.0	2.8	0.0	1.4
Brookline	63.0	32.2	4.8	0.0	0.0	95.2	3.7	1.1	0.0	0.0
Cambridge	1.8	46.2	43.0	9.0	0.0	0.0	0.7	30.8	58.7	9.8
Canton	86.3	9.4	3.2	1.1	0.0	97.9	1.0	1.1	0.0	0.0
Chelmsford	78.5	20.6	0.0	0.9	0.0	92.5	5.6	1.9	0.0	0.0
Chelsea	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Cheshire	11.8	78.5	7.8	1.9	0.0	17.6	51.0	25.5	5.9	0.0
Chester	5.0	95.0	0.0	0.0	0.0	5.0	20.0	70.0	5.0	0.0
Chicopee	21.6	51.2	25.3	1.9	0.0	41.4	12.9	30.3	14.8	0.6
Clinton	4.5	64.4	31.1	0.0	0.0	0.0	18.9	60.0	21.1	0.0
Cohasset	41.3	28.2	20.6	9.9	0.0	58.2	24.3	13.5	4.0	0.0
Colrain	30.0	70.0	0.0	0.0	0.0	23.3	40.0	33.4	3.3	0.0
Concord	26.4	56.6	9.4	7.6	0.0	5.7	35.9	49.0	9.4	0.0
Cummington*	...	...	...	...	...	...	...	...	...	...
Dalton	9.8	82.0	8.2	0.0	0.0	0.0	27.8	41.0	31.2	0.0
Danvers	10.0	78.3	11.7	0.0	0.0	0.0	15.0	30.0	46.7	8.3
Dartmouth	9.3	74.0	15.5	1.2	0.0	0.0	2.5	36.0	47.8	13.7
Dedham	98.0	2.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Deerfield	61.3	33.9	4.8	0.0	0.0	29.0	37.2	30.6	3.2	0.0
Douglas	38.8	47.8	11.9	1.5	0.0	100.0	0.0	0.0	0.0	0.0
Dracut	67.0	25.9	5.3	1.8	0.0	96.4	1.8	1.8	0.0	0.0
Dudley	88.5	11.5	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Dunstable*	...	...	...	...	...	...	...	...	...	...
Duxbury	96.8	3.2	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0

TABLE 2. — *Continued.*

City or Town.	Sediment.					Odor.				
	None.	Very Slight.	Slight.	Considerable.	High	None.	Very Faint.	Faint.	Distinct.	Decided and Strong
E. Bridgewater	23.0	49.2	24.3	3.5	0.0	41.2	30.6	20.8	7.4	0.0
Easthampton	82.4	13.2	4.4	0.0	0.0	100.0	0.0	0.0	0.0	0.0
E. Longmeadow	28.1	44.7	21.1	6.1	0.0	23.6	14.6	32.6	25.7	3.5
Easton	98.0	2.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Edgartown	90.0	10.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Egremont	57.8	38.4	3.8	0.0	0.0	23.0	46.2	30.8	0.0	0.0
Erving	34.6	46.2	17.3	1.9	0.0	13.5	28.8	40.4	17.3	0.0
Everett	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Fairhaven	87.5	10.4	2.1	0.0	0.0	66.6	20.9	6.2	4.2	2.1
Fall River	0.8	53.0	42.0	4.2	0.0	0.0	7.6	64.7	25.2	2.5
Falmouth	16.6	79.7	3.7	0.0	0.0	7.4	35.2	46.3	7.4	3.7
Fitchburg	7.2	51.7	33.5	7.2	0.4	1.7	9.3	53.0	34.4	1.6
Foxborough	93.1	6.9	0.0	0.0	0.0	96.5	0.0	3.5	0.0	0.0
Framingham	65.5	29.6	4.9	0.0	0.0	93.7	3.5	2.1	0.7	0.0
Franklin	93.0	5.6	1.4	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Gardner	11.2	74.2	13.5	1.1	0.0	1.7	17.4	38.2	33.7	9.0
Gill*	...	...	...	...	...	...	...	...	...	...
Gloucester	7.8	70.5	21.7	0.0	0.0	0.0	4.5	43.0	47.5	5.0
Grafton	72.2	25.0	2.8	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Granville	87.8	12.2	0.0	0.0	0.0	84.9	15.1	0.0	0.0	0.0
Great Barrington	15.6	55.5	22.6	6.3	0.0	10.9	37.5	39.1	10.9	1.6
Greenfield	8.5	73.2	12.2	6.1	0.0	3.6	46.3	39.0	1.1	0.0
Groton	96.0	4.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Groveland*	...	...	...	...	...	...	...	...	...	...
Hadley	24.4	64.5	11.1	0.0	0.0	4.5	24.4	62.2	8.9	0.0
Hardwick*	...	...	...	...	...	...	...	...	...	...
Hatfield	28.6	65.3	4.1	2.0	0.0	6.1	26.6	55.0	12.3	0.0
Haverhill	12.6	65.3	19.9	2.2	0.0	0.5	9.5	48.5	37.0	4.5
Hingham	23.8	61.0	11.3	3.9	0.0	18.8	13.4	33.6	26.8	7.4
Hinsdale	22.2	66.7	7.4	3.7	0.0	11.1	18.5	44.5	22.2	3.7
Holbrook	59.6	36.2	4.2	0.0	0.0	87.3	4.3	6.3	2.1	0.0
Holden	41.5	54.7	3.8	0.0	0.0	1.9	39.6	45.5	13.0	0.0
Holliston	8.0	56.0	36.0	0.0	0.0	28.0	16.0	20.0	36.0	0.0
Holyoke	5.5	55.8	35.5	3.2	0.0	0.2	11.1	55.3	31.2	2.2
Hopedale	63.6	36.4	0.0	0.0	0.0	85.0	9.0	4.5	1.5	0.0
Hopkinton	71.8	25.6	2.6	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Hudson	1.2	62.5	28.4	7.9	0.0	0.0	12.5	43.3	36.3	7.9
Hull	23.8	61.0	11.3	3.9	0.0	18.8	13.4	33.6	26.8	7.4
Huntington	57.2	38.0	4.8	0.0	0.0	19.0	23.8	52.5	4.7	0.0
Hyde Park†	52.5	23.3	19.2	5.0	0.0	72.5	19.8	7.7	0.0	0.0
Ipswich	0.0	52.7	47.3	0.0	0.0	0.0	4.0	43.3	48.7	4.0
Kingston	81.6	18.4	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Lancaster	4.4	64.5	31.1	0.0	0.0	0.0	18.9	60.0	21.1	0.0
Lawrence	20.8	51.5	24.9	2.8	0.0	0.0	84.2	15.8	0.0	0.0
Lee	16.8	76.5	4.5	2.2	0.0	1.1	21.4	57.3	20.2	0.0
Leicester	59.7	33.3	5.8	1.2	0.0	74.7	13.8	10.3	1.2	0.0
Lenox	14.3	61.9	17.5	6.3	0.0	6.4	44.5	36.5	11.1	1.5
Leominster	0.4	34.7	45.0	19.5	0.4	0.8	11.9	49.2	34.3	3.8
Lexington	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Lincoln	16.7	66.7	13.3	3.3	0.0	11.7	25.0	43.3	18.3	1.7
Littleton	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Longmeadow	26.5	46.0	21.6	5.9	0.0	22.1	15.2	33.6	25.5	3.6
Lowell	7.7	28.9	35.8	27.6	0.0	67.3	26.7	5.6	0.4	0.0
Ludlow	28.1	44.7	21.0	6.2	0.0	23.6	14.3	32.6	25.8	3.7
Lynn	1.0	56.7	37.8	4.5	0.0	0.0	1.7	30.0	56.8	11.5

* No figures. † Hyde Park for years 1910–1911

TABLE 2. — *Continued.*

City or Town.	Sediment.					Odor.				
	None.	Very Slight	Slight.	Considerable.	High	None.	Very Faint.	Faint.	Distinct.	Decided and Strong
Malden	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Manchester	15.8	69.1	13.2	1.9	0.0	34.7	8.0	26.0	20.0	11.3
Mansfield	96.4	3.6	0.0	0.0	0.0	98.2	0.0	1.8	0.0	0.0
Marblehead	56.3	17.8	5.2	20.0	0.7	88.2	8.1	3.7	0.0	0.0
Marion	94.7	4.2	1.1	0.0	0.0	98.9	0.0	1.1	0.0	0.0
Marlborough	4.9	53.1	37.8	4.2	0.0	0.0	7.7	44.7	42.7	4.9
Marshfield	88.2	11.8	0.0	0.0	0.0	88.2	11.8	0.0	0.0	0.0
Mattapoisett	83.0	7.7	1.5	7.8	0.0	97.0	3.0	0.0	0.0	0.0
Maynard	17.6	73.6	5.9	2.9	0.0	0.0	17.6	56.0	26.4	0.0
Medfield	17.3	79.3	3.4	0.0	0.0	89.7	6.9	3.4	0.0	0.0
Medford	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Medway	79.2	12.5	8.3	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Melrose	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Merrimac	86.2	9.8	4.0	0.0	0.0	98.0	0.0	2.0	0.0	0.0
Methuen	9.6	68.4	18.2	3.8	0.0	81.8	14.4	2.9	0.9	0.0
Middleborough	27.0	9.9	20.4	38.8	3.9	82.3	15.1	1.9	0.7	0.0
Middleton	10.0	78.3	11.7	0.0	0.0	0.0	15.0	30.0	46.7	8.3
Milford	63.6	36.4	0.0	0.0	0.0	85.0	9.0	4.5	1.5	0.0
Millbury	79.5	16.4	4.1	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Millis	92.6	7.4	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Milton	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Monson	73.8	26.2	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Montague	34.6	46.2	17.3	1.9	0.0	13.5	28.8	40.4	17.3	0.0
Monterey*	...	...	...	...	...	...	...	...	...	...
Nahant	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.0
Nantucket	12.5	39.8	39.8	7.9	0.0	26.2	6.8	36.3	28.4	2.3
Natick	98.0	2.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Needham	88.5	11.5	0.0	0.0	0.0	99.3	0.0	0.7	0.0	0.0
New Bedford	9.3	74.0	15.5	1.2	0.0	0.0	2.5	36.0	47.8	13.7
Newburyport	16.8	49.5	27.2	6.5	0.0	64.0	7.0	10.9	13.0	5.1
Newton	51.6	37.5	10.9	0.0	0.0	95.3	1.5	1.6	1.6	0.0
North Adams	9.8	69.8	15.5	4.9	0.0	8.5	38.8	44.3	8.4	0.0
Northampton	5.0	59.2	33.3	2.5	0.0	0.0	19.2	41.7	35.8	3.3
North Andover	5.2	74.6	21.1	0.0	0.0	1.8	8.9	48.2	35.7	5.4
N. Attleborough	74.0	16.7	9.3	0.0	0.0	98.0	2.0	0.0	0.0	0.0
Northborough	3.3	37.3	49.2	10.2	0.0	0.0	1.6	18.7	61.0	18.7
Northbridge	22.0	49.2	20.4	8.4	0.0	10.2	23.8	44.0	13.5	8.5
N. Brookfield	1.4	25.4	55.3	17.9	0.0	0.0	2.9	31.4	62.7	3.0
Northfield	78.3	21.7	0.0	0.0	0.0	0.0	34.8	56.5	8.7	0.0
Norton	93.0	4.7	2.3	0.0	0.0	97.7	0.0	2.3	0.0	0.0
Norwood	14.3	44.0	34.5	7.2	0.0	49.0	6.6	21.0	21.6	1.8
Oak Bluffs	66.0	34.0	0.0	0.0	0.0	98.0	2.0	0.0	0.0	0.0
Orange	30.3	66.7	3.0	0.0	0.0	24.2	15.3	54.0	6.0	0.0
Oxford	94.0	6.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Palmer	35.5	36.4	25.6	2.5	0.0	58.6	0.8	23.2	14.1	3.3
Peabody	3.9	55.8	39.0	1.3	0.0	1.9	9.1	44.8	39.0	5.2
Pepperell	95.5	3.0	1.5	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Pittsfield	10.6	68.0	18.7	2.7	0.0	0.3	20.2	40.2	33.0	6.3
Plainville	47.8	13.3	22.2	16.7	0.0	96.7	2.2	0.0	1.1	0.0
Plymouth	4.1	69.7	26.2	0.0	0.0	10.7	45.1	33.6	9.8	0.8
Provincetown	95.5	4.5	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Quincy	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Randolph	11.7	80.0	8.3	0.0	0.0	0.0	6.7	35.0	53.3	5.0
Reading	36.5	11.3	5.7	44.6	1.9	54.1	23.2	17.0	5.7	0.0
Revere	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Rockland	28.0	54.0	16.0	2.0	0.0	2.0	24.0	50.0	22.0	2.0

TABLE 2. — *Continued.*

City or Town.	Sediment.					Odor.				
	None.	Very Slight.	Slight.	Considerable.	High.	None.	Very Faint.	Faint.	Distinct.	Decided and Strong.
Rockport	0.0	28.3	50.0	21.7	0.0	0.0	1.7	25.0	53.3	20.0
Russell	61.8	31.0	3.6	3.6	0.0	5.5	21.8	56.3	10.9	5.5
Rutland	41.5	54.7	3.8	0.0	0 0	1.9	39.6	45.5	13.0	0.0
Salem	15.1	26.6	40.4	17.3	0.6	6.2	15.5	18.2	40.9	19.2
Salisbury	50.0	46.2	3.8	0.0	0.0	61.5	15.4	23.1	0.0	0.0
Saugus	1.0	56.7	37.8	4.5	0.0	0.0	1.7	30.0	56.8	11.5
Scituate	69.3	22.6	8.1	0.0	0.0	80.7	8.1	4.8	4 8	1.6
Sharon	91.0	5.1	3.9	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Sheffield	60.0	40.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Shelburne	67.6	32.4	0.0	0.0	0.0	38.3	26.5	26.4	8.8	0.0
Shirley	86.8	11.3	1.9	0.0	0.0	98.1	1.9	0.0	0.0	0.0
Shrewsbury	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Somerville	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
South Hadley	25.4	33.3	33 3	8.0	0.0	24.4	10.4	36.3	24.4	4.5
Southampton*	...	...	...	...	...	...	...	...	...	...
Southbridge	9.2	51.7	35.0	4.1	0.0	0.0	11.6	48.4	38.6	1.4
Spencer	58.3	39.0	2.7	0.0	0.0	5.5	19.5	55.5	19.5	0.0
Springfield	28.1	44.7	21.0	6.2	0.0	23.6	14.3	32.6	25.8	3.7
Stockbridge	20.9	61.4	17.7	0.0	0.0	0.0	19.3	32.3	43.6	4.8
Stoneham	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Stoughton	34.2	63.2	2.6	0.0	0.0	18.6	23.6	36.8	21.0	0.0
Sunderland*	...	...	...	...	...	...	...	...	...	...
Swampscott	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Taunton	5.6	77.5	16.9	0.0	0.0	0.8	12.9	46.8	37.1	2.4
Tisbury	80.5	13.0	6.5	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Uxbridge	88.2	11.8	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Wakefield	0.9	55.4	35.7	8.0	0.0	0.0	0.9	33.0	54.5	11.6
Walpole	75.0	25.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Waltham	56.9	33.9	7.9	1.3	0.0	98.8	0.8	0.4	0.0	0.0
Ware	98.1	1.9	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Wareham	66.7	31.8	1.5	0.0	0.0	64.4	14.3	18.2	3.1	0.0
Watertown	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Wayland	0.0	69.2	28.2	2.6	0.0	0.0	0.0	15.4	64.1	20.5
Webster	51.0	34.1	14.9	0.0	0.0	97.9	2.1	0.0	0.0	0.0
Wellesley	79.5	20.5	0.0	0.0	0.0	99.3	0.7	0.0	0.0	0.0
Westborough	13.2	77.3	9.5	0.0	0.0	3.8	22.6	66.1	7.5	0.0
W. Bridgewater	3.7	59.5	32.5	4.3	0.0	11.0	46.0	31.9	11.1	0.0
W. Brookfield	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Westfield	12.4	50.4	31.0	6.2	0.0	1.7	15.0	39.9	38.1	5.3
Westford	98.5	1.5	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Westhampton*	...	...	...	...	...	...	...	...	...	...
Weston	83.6	16.4	0.0	0.0	0.0	96.4	0.0	3.6	0.0	0.0
W. Springfield	56.1	34.1	9.8	0.0	0.0	80.2	14.5	4.0	1.3	0.0
W. Stockbridge*	...	...	...	...	...	...	...	...	...	...
Westwood*	...	...	...	...	...	...	...	...	...	...
Weymouth	11.5	67.3	21.2	0.0	0.0	0.0	7.7	32.7	50.0	9.6
Whitman	3.7	59.5	32.5	4.3	0.0	11.1	46.0	31.9	11.0	0.0
Williamsburg	6.2	73.0	20.8	0.0	0.0	2.1	33.2	48.0	16.7	0.0
Williamstown	25.7	65.7	5.7	2.9	0.0	20.0	31.4	37.2	11.4	0.0
Winchendon	38.0	25.0	22.0	15.0	0.0	87.0	10.0	2.0	1.0	0.0
Winchester	2.0	63.9	31.1	3.0	0.0	0.0	8.2	52.3	36.5	3 0
Winthrop	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Woburn	99.0	1.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Worcester	4.2	61.2	29.6	5.0	0.0	0.2	9.1	56.4	32.7	1.6
Worthington	50.0	42.5	5.0	2.5	0.0	75.0	12.5	10.0	2.5	0.0
Wrentham	92.3	7.7	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0

* No figures.

TABLE 3.

Public Water Supplies of Massachusetts.

AVERAGE COLOR.

1910–1919.

City or Town.	Color.	City or Town.	Color	City or Town.	Color.
Acton	0	Attleborough	4	Barre	15
Avon	0	Bedford	4	Billerica	15
Barnstable	0	Deerfield	4	Clinton	15
Brookfield (East)	0	Dracut	4	Lancaster	15
Duxbury	0	Monson	4	Williamsburg	15
Dudley	0	Williamstown	4	Fall River	16
Easthampton	0	Worthington	4	North Andover	16
Easton	0	Dedham	5	Braintree	17
Edgartown	0	Greenfield	5	Holbrook	17
Foxborough	0	Shelburne	5	Northbridge	17
Franklin	0	Ashburnham	6	Amesbury	18
Groton	0	Bridgewater	6	Hyde Park*	18
Hopkinton	0	Canton	6	Northampton	18
Kingston	0	Colrain	6	Norwood	18
Littleton	0	Concord	6	Taunton	19
Mansfield	0	Erving	6	Worcester	19
Marion	0	Grafton	6	Leominster	20
Marshfield	0	Holden	6	Maynard	20
Mattapoisett	0	Lincoln	6	Russell	20
Medfield	0	Manchester	6	Hinsdale	21
Millis	0	Montague	6	Holyoke	21
Natick	0	Rutland	6	Hopedale	21
Norton	0	Waltham	6	Milford	21
Oak Bluffs	0	Adams	7	Northfield	21
Oxford	0	Blandford	7	Wakefield	21
Pepperell	0	Lenox	7	Middleborough	22
Scituate	0	Spencer	7	Fitchburg	24
Sheffield	0	Woburn	7	Hingham	24
Shirley	0	East Bridgewater	8	Hull	24
Shrewsbury	0	Great Barrington	8	Peabody	24
Uxbridge	0	Abington	9	Stoughton	24
Walpole	0	Gardner	9	Haverhill	26
Ware	0	Hadley	9	Metropolitan District	
Wellesley	0	Hudson	9	Arlington	26
West Brookfield	0	Huntington	9	Belmont	26
Westford	0	North Adams	9	Boston	26
Wrentham	0	Rockland	9	Chelsea	26
Ashland	1	Brockton	10	Everett	26
Ayer	1	Chester	10	Lexington	26
Cheshire	1	Leicester	10	Malden	26
Douglas	1	Nantucket	10	Medford	26
Falmouth	1	Orange	10	Melrose	26
Granville	1	South Hadley	10	Milton	26
Medway	1	West Bridgewater	10	Nahant	26
Merrimac	1	Whitman	10	Quincy	26
Needham	1	Winchendon	10	Revere	26
North Attleborough	1	Longmeadow	11	Somerville	26
Provincetown	1	West Springfield	11	Stoneham	26
Sharon	1	Hatfield	12	Swampscott	26
Tisbury	1	Newburyport	12	Watertown	25
Wareham	1	Palmer	12	Winthrop	26
Egremont	2	Winchester	12	Pittsfield	26
Millbury	2	Brookline	13	Southbridge	26
Newton	2	Chelmsford (North)	13	Chicopee	27
Plymouth	2	Marblehead	13	Dalton	27
Webster	2	Stockbridge	13	Ipswich	28
Framingham	3	Weston	13	Agawam	29
Plainville	3	Andover	14	East Longmeadow	29
Westborough	3	Salisbury	14	Lee	29

TABLE 3. — *Continued.*

City or Town.	Color.	City or Town.	Color.	City or Town.	Color.
Lowell	29	Fairhaven	42	Wayland	85
Ludlow	29	Cambridge	43	Blackstone	*
Marlborough	29	Lynn	46	Cummington	*
Methuen	29	Saugus	46	Dunstable	*
Springfield	29	North Brookfield	47	Gill	*
Westfield	29	Reading	49	Groveland	*
Ashfield	30	Holliston	50	Hardwick	*
Lawrence	31	Danvers	52	Monterey	*
Amherst	32	Middleton	52	Southampton	*
Rockport	32	Athol	59	Sunderland	*
Acushnet	39	Northborough	61	West Stockbridge	*
Dartmouth	39	Cohasset	63	Westhampton	*
Gloucester	39	Weymouth	65	Westwood	*
New Bedford	39	Beverly	72		
Randolph	41	Salem	72		

* No figures available.

TABLE 4.

Public Water Supplies of Massachusetts.

AVERAGE CHLORINE.

Parts per Million.

1910–1919.

City or Town.	Chlorine.	City or Town.	Chlorine.	City or Town.	Chlorine
Sheffield	0.9	Montague	1.7	Gardner	3.1
Hinsdale	1.0	Springfield	1.7	Holden	3.2
North Adams	1.0	Amherst	1.8	Northborough	3.2
Williamstown	1.0	Athol	1.8	Rutland	3.2
Dalton	1.1	Holyoke	1.8	South Hadley	3.3
Lenox	1.1	Westford	1.8	Oxford	3.4
Shelburne	1.1	Chicopee	1.9	Concord	3.5
Worthington	1.1	Monson	1.9	Leicester	3.5
Adams	1.2	North Brookfield	1.9	Webster	3.5
Cheshire	1.2	Palmer	1.9	Plainville	3.6
Egremont	1.2	Blandford	2.0	Wrentham	3.6
Lee	1.2	Hadley	2.0	Bedford	3.7
Pittsfield	1.2	Hatfield	2.0	Hopedale	3.7
Stockbridge	1.2	Pepperell	2.0	Metropolitan District	
Ashfield	1.3	Ashburnham	2.1	Arlington	3.7
Great Barrington	1.3	Fitchburg	2.1	Belmont	3.7
Chester	1.4	Leominster	2.1	Boston	3.7
Northfield	1.4	Southbridge	2.1	Chelsea	3.7
Orange	1.4	Spencer	2.1	Everett	3.7
Colrain	1.5	Barre	2.2	Lexington	3.7
Deerfield	1.5	Groton	2.2	Malden	3.7
Granville	1.5	Longmeadow	2.2	Medford	3.7
Northampton	1.5	Brookfield (East)	2.3	Melrose	3.7
Williamsburg	1.5	Clinton	2.3	Milton	3.7
Winchendon	1.5	Lancaster	2.3	Nahant	3.7
Easthampton	1.6	Littleton	2.4	Quincy	3.7
Huntington	1.6	Dudley	2.5	Revere	3.7
Russell	1.6	Northbridge	2.5	Somerville	3.7
Westfield	1.6	West Springfield	2.5	Stoneham	3.7
Agawam	1.7	Worcester	2.6	Swampscott	3.7
East Longmeadow	1.7	Hudson	2.7	Watertown	3.7
Erving	1.7	West Brookfield	2.7	Winthrop	3.7
Greenfield	1.7	Westborough	2.9	Milford	3.7
Ludlow	1.7	Maynard	3.0	Millbury	3.7

TABLE 4 — *Continued.*

City or Town.	Chlorine.	City or Town.	Chlorine.	City or Town.	Chlorine.
Douglas	3.8	Dartmouth	5.8	Tisbury	9.7
Lincoln	3.8	Medway	5.8	Oak Bluffs	9.8
Wayland	3.8	New Bedford	5.8	Beverly	9.9
Andover	3.9	Plymouth	5.8	Salem	9.9
Ashland	3.9	Norwood	5.9	Falmouth	10.1
Norton	3.9	Acton	6.0	Dedham	10.5
Holliston	4.0	Easton	6.0	Sharon	10.5
Shirley	4.0	Salisbury	6.0	Fairhaven	10.6
Stoughton	4.0	Bridgewater	6.3	Barnstable	11.6
Danvers	4.1	Brockton	6.4	Braintree	11.7
Middleton	4.1	East Bridgewater	6.4	Holbrook	11.7
Ware	4.1	Wareham	6.4	Hopkinton	11.8
Billerica	4.2	West Bridgewater	6.4	Wellesley	11.8
Medfield	4.2	Weston	6.4	Grafton	14.1
Walpole	4.4	Whitman	6.4	Manchester	14.2
Dracut	4.5	Fall River	6.5	Cohasset	15.7
Mansfield	4.5	Middleborough	6.7	Hyde Park*	18.1
Winchester	4.5	Randolph	6.9	Nantucket	21.8
Foxborough	4.6	Abington	7.2	Framingham	21.8
Haverhill	4.6	Marion	7.2	Reading	30.0
Methuen	4.6	Rockland	7.2	Scituate	34.2
Chelmsford (North)	4.7	Hingham	7.3	Rockport	49.9
Lawrence	4.7	Hull	7.3	Marblehead	50.5
North Andover	4.7	Needham	7.3	Provincetown	59.2
Canton	4.9	Kingston	7.5	Woburn	59.3
Lowell	4 9	Waltham	7.5	Marshfield	88.0
Franklin	5.1	Natick	7.6		
Marlborough	5.1	Millis	7.7	Blackstone	†
Ayer	5.2	Newburyport	7.7	Cummington	†
Newton	5.2	Lynn	7.8	Dunstable	†
Shrewsbury	5.2	Saugus	7.8	Gill	†
Attleborough	5.3	Brookline	7.9	Groveland	†
Merrimac	5.3	Ipswich	7.9	Hardwick	†
North Attleborough	5.4	Wakefield	8.2	Monterey	†
Avon	5.5	Duxbury	8.6	Southampton	†
Cambridge	5.5	Peabody	9.0	Sunderland	†
Weymouth	5.5	Edgartown	9.3	West Stockbridge	†
Taunton	5.6	Mattapoisett	9.3	Westhampton	†
Uxbridge	5.7	Amesbury	9.4	Westwood	†
Acushnet	5.8	Gloucester	9.7		

*Hyde Park for years 1910 and 1911. † No Figures.

TABLE 5.

Public Water Supplies of Massachusetts.

AVERAGE HARDNESS.

Parts per Million.

1910–1919.

City or Town.	Hardness.	City or Town.	Hardness.	City or Town.	Hardness.
Edgartown	4	Barnstable	7	Montague	8
Falmouth	4	Brockton	7	Oak Bluffs	8
Gloucester	5	Brookfield (East)	7	Southbridge	8
Leominster	5	Fitchburg	7	Taunton	8
Wareham	5	Hinsdale	7	Weymouth	8
Duxbury	6	Maynard	7	Acushnet	9
Northbridge	6	Rockland	7	Dartmouth	9
Tisbury	6	West Bridgewater	7	New Bedford	9
Westfield	6	Whitman	7	North Brookfield	9
Abington	7	Amherst	8	Plymouth	9
Ashburnham	7	Erving	8	Fall River	10

TABLE 5 — *Continued.*

City or Town.	Hardness.
Holden	10
Orange	10
Rutland	10
Spencer	10
Stoughton	10
Winchendon	10
Dudley	11
Marion	11
Monson	11
Northfield	11
South Hadley	11
Agawam	12
Athol	12
Clinton	12
East Longmeadow	12
Kingston	12
Lancaster	12
Ludlow	12
Northborough	12
Shirley	12
Springfield	12
West Brookfield	12
Worthington	12
Wrentham	12
Ashland	13
Barre	13
Chicopee	13
Hingham	13
Hull	13
Randolph	13
Worcester	13
Metropolitan District	
Arlington	14
Belmont	14
Boston	14
Chelsea	14
Everett	14
Lexington	14
Malden	14
Medford	14
Melrose	14
Milton	14
Nahant	14
Quincy	14
Revere	14
Somerville	14
Stoneham	14
Swampscott	14
Watertown	14
Winthrop	14
Foxborough	14
Hudson	14
Palmer	14
Pepperell	14
Russell	14
Westborough	14
Andover	15
Canton	15
Dalton	15
Holliston	15
Lawrence	15
Nantucket	15
Winchester	15
Bedford	16
Blandford	16
Franklin	16
Mansfield	16
Medfield	16
Wayland	16
Westford	16
Chester	17
Concord	17
Douglas	17
East Bridgewater	17
Easton	17
Lincoln	17
Norton	17
Sheffield	17
Shrewsbury	17
Webster	17
Danvers	18
Hopedale	18
Littleton	18
Marlborough	18
Middleton	18
Milford	18
North Andover	18
Oxford	18
Uxbridge	18
Walpole	18
Chelmsford (North)	19
Hadley	19
Huntington	19
Northampton	19
Williamsburg	19
Attleborough	20
Gardner	20
Granville	20
Holyoke	20
Ipswich	20
Lee	20
Hatfield	21
Wakefield	21
Avon	22
Mattapoisett	22
Millbury	22
Peabody	22
Plainville	22
Rockport	22
Lynn	23
Saugus	23
Ware	23
Beverly	24
Leicester	24
Needham	24
North Attleborough	24
Salem	24
Manchester	25
Middleborough	25
Ayer	26
Cambridge	26
Egremont	26
Fairhaven	26
Longmeadow	26
Merrimac	26
Ashfield	27
Braintree	27
Bridgewater	27
Holbrook	27
Lowell	27
Newton	27
Norwood	27
Billerica	28
Newburyport	28
Provincetown	28
Groton	29
Medway	29
Deerfield	31
Methuen	31
Weston	31
Greenfield	32
Shelburne	32
Acton	35
Sharon	35
West Springfield	36
Waltham	37
Millis	38
Brookline*	39
Dracut	39
Easthampton	39
Colrain	40
Dedham	41
Pittsfield	42
Salisbury	42
Wellesley	42
North Adams	43
Grafton	45
Natick	46
Stockbridge	49
Woburn	49
Cohasset	50
Framingham	50
Hyde Park*	54
Cheshire	55
Hopkinton	50
Adams	56
Great Barrington	57
Lenox	58
Marshfield	58
Williamstown	64
Haverhill	62
Reading	65
Scituate	77
Marblehead	79
Amesbury	100
Blackstone	†
Cummington	†
Dunstable	†
Gill	†
Groveland	†
Hardwick	†
Monterey	†
Southampton	†
Sunderland	†
West Stockbridge	†
Westhampton	†
Westwood	†

* Hyde Park for years 1910 and 1912. † No figures available.

TABLE 6.

PUBLIC WATER SUPPLIES OF MASSACHUSETTS.

AVERAGE IRON.

Parts per Million.

1910–1919.

City or Town.	Iron.	City or Town.	Iron.	City or Town.	Iron.
Mansfield	0.02	Granville	0.10	Spencer	0.15
Oxford	0.04	Hadley	0.10	Amherst	0.16
Dudley	0.05	Sharon	0.10	Cambridge	0.16
Edgartown	0.05	West Bridgewater	0.10	Canton	0.16
Littleton	0.05	Whitman	0.10	Hudson	0.16
Natick	0.05	Adams	0.11	Huntington	0.16
Pepperell	0.05	Clinton	0.11	Marblehead	0.16
Shirley	0.05	Fairhaven	0.11	Pittsfield	0.16
Ware	0.05	Fall River	0.11	Russell	0.16
Acton	0.06	Framingham	0.11	Shelburne	0.16
Brookfield (East)	0.06	Great Barrington	0.11	Stockbridge	0.16
Chester	0.06	Lancaster	0.11	Wellesley	0.16
Colrain	0.06	Lenox	0.11	Worcester	0.16
Duxbury	0.06	North Attleborough	0.11	Acushnet	0.17
Hatfield	0.06	Tisbury	0.11	Braintree	0.17
Marion	0.06	Ashburnham	0.12	Danvers	0.17
Mattapoisett	0.06	Ayer	0.12	Dartmouth	0.17
Millis	0.06	Greenfield	0.12	Haverhill	0.17
Scituate	0.06	Hopkinton	0.12	Holbrook	0.17
Shrewsbury	0.06	Lincoln	0.12	Longmeadow	0.17
West Brookfield	0.06	Orange	0.12	Middleton	0.17
Andover	0.07	Stoughton	0.12	New Bedford	0.17
Dedham	0.07	Westborough	0.12	Dracut	0.18
Easton	0.07	Dalton	0.13	Gardner	0.18
Medway	0.07	Merrimac	0.13	Ipswich	0.18
Monson	0.07	Provincetown	0.13	Ashfield	0.19
Needham	0.07	Taunton	0.13	Hopedale	0.19
Norton	0.07	Marshfield	0.14	Milford	0.19
Uxbridge	0.07	Millbury	0.14	Abington	0.20
Wareham	0.07	Northampton	0.14	Bedford	0.20
Westford	0.07	Webster	0.14	Rockland	0.20
Weston	0.07	Metropolitan District		Concord	0.21
Attleborough	0.08	Arlington	0.15	Peabody	0.21
Avon	0.08	Belmont	0.15	North Adams	0.22
Barnstable	0.08	Boston	0.15	Randolph	0.22
Easthampton	0.08	Chelsea	0.15	Williamsburg	0.22
Egremont	0.08	Everett	0.15	East Bridgewater	0.23
Groton	0.08	Lexington	0.15	North Andover	0.23
Medfield	0.08	Malden	0.15	Winchester	0.23
Newton	0.08	Medford	0.15	Erving	0.24
Oak Bluffs	0.08	Melrose	0.15	Montague	0.24
Sheffield	0.08	Milton	0.15	Plymouth	0.24
Woburn	0.08	Nahant	0.15	Westfield	0.24
Ashland	0.09	Quincy	0.15	Barre	0.25
Cheshire	0.09	Revere	0.15	Maynard	0.25
Falmouth	0.09	Somerville	0.15	West Springfield	0.25
Foxborough	0.09	Stoneham	0.15	Northbridge	0.26
Franklin	0.09	Swampscott	0.15	Wakefield	0.26
Holden	0.09	Watertown	0.15	Williamstown	0.26
Kingston	0.09	Winthrop	0.15	Leominster	0.27
Northfield	0.09	Brookline	0.15	Salisbury	0.27
Rutland	0.09	Grafton	0.15	South Hadley	0.27
Walpole	0.09	Hingham	0.15	Northborough	0.28
Wrentham	0.09	Hull	0.15	Holyoke	0.29
Blandford	0.10	Lee	0.15	Worthington	0.29
Brockton	0.10	Leicester	0.15	Weymouth	0.30
Deerfield	0.10	Manchester	0.15	Southbridge	0.31

TABLE 6 — *Continued.*

City or Town.	Iron.	City or Town.	Iron.	City or Town.	Iron.
Waltham	0.31	Wayland	0.38	Amesbury	1.34
Agawam	0.32	Hyde Park*	0.43	Middleborough	1.45
Athol	0.32	Douglas	0.45	Reading	1.72
Chelmsford (North)	0.32	Newburyport	0.48	Blackstone	†
East Longmeadow	0.32	Gloucester	0.52	Cummington	†
Ludlow	0.32	Cohasset	0.63	Dunstable	†
Lynn	0.32	Methuen	0.68	Gill	†
Saugus	0.32	Hinsdale	0.69	Groveland	†
Springfield	0.32	Billerica	0.71	Hardwick	†
Chicopee	0.33	North Brookfield	0.76	Monterey	†
Marlborough	0.33	Lawrence	0.85	Southampton	†
Plainville	0.33	Beverly	0.86	Sunderland	†
Bridgewater	0 36	Salem	0.86	West Stockbridge	†
Nantucket	0.36	Winchendon	0.88	Westhampton	†
Norwood	0.36	Rockport	0.90	Westwood	†
Fitchburg	0.38	Holliston	0.92		
Palmer	0.38	Lowell	0.96		

*Hyde Park for years 1910 and 1911.

† No figures available.

TABLE 7.

Corrosion Factors.

(Miscellaneous Data.)

City or Town.	Number of Observations.	Parts per Million. Free CO_2	Alkalinity.
Abington	6	1.6	5.2
Andover	5	1.3	11.4
Ashburnham	1	3.1	13.0
Boston	1	11.0	13.0
Braintree	3	1.4	9.6
Brookline	4	12.2	48.2
Brockton	5	1.7	8.1
Chicopee	2	3.4	9.2
Dracut	1	3.1	42.0
Fairhaven	1	21.7	12.0
Haverhill	12	1.4	16.8
Hingham	10	6.0	8.2
Ipswich	1	7.8	15.5
Kingston	1	20.3	11.5
Lawrence	7	4.2	12.3
Lincoln	1	5.5	3.0
Lowell	8	20.6	31.0
Marblehead	2	5.7	34.0
Marlborough	5	3.3	7.6
Methuen	1	2.9	28.0
Middleborough	1	41.4	17.5
Milford	1	15.2	10.5
Millbury	1	29.5	15.5
New Bedford	1	9.5	9.0
Newburyport	3	6.7	24.8
Newton	4	18.8	29.2
North Andover	5	1.4	14.0
North Easton	1	23.4	10.0
Norwood	14	8.1	8.3
Palmer	1	5.0	10.5
Provincetown	1	37.4	3.9
Reading	1	16.4	63.0
Revere	1	7.4	59.0
Sharon	1	15.1	27.0
South Hadley	2	6.0	8.7
Springfield	3	1.1	8.1
Stoughton	12	11.2	7.5
Wakefield	5	1.8	15.9
Waltham	3	29.3	37.3
Wellesley	1	19.8	16.0
West Brookfield	1	15.2	8.0
Weymouth	3	4.2	5.0
Winchester	10	1.3	8.5
Woburn	3	13.1	51.1
Wachusett Reservoir	13	1.3	8.4
Sudbury Reservoir	7	2.3	8.4
Lake Cochituate	13	1.8	18.3
Framingham Reservoir, No. 2	2	1.1	11.0
Framingham Reservoir, No. 3	4	1.3	8.8
Hopkinton Reservoir	7	3.9	7.5
Ashland Reservoir	7	3.2	6.9
Spot Pond	2	0.6	9.0
Jamaica Pond	2	0.0	29.0
Upper Mystic Lake	5	3.1	12.6
Lower Mystic Lake	5	0.4	34.9

TABLE 8.

Aggressive Carbonic Acid.

(Parts per Million.)

City or Town.	Supply Surface or Ground.	Hardness 1905 to 1909.	Alkalinity.	Free Carbonic Acid.	Aggressive Carbonic Acid.
Abington	S	5	5.2	1.6	1.6
Andover	S	11	11.4	1.3	1.3
Ashburnham	S	10	13.0	3.1	3.1
Boston	S	13*	13.0	11.0	11.0
Braintree	S & G	10 & 19	9.6	1.4	1.4
Brookline	G	46	48.2	12.2	11.7
Brockton	S	5	8.1	1.7	1.7
Chicopee	S	9	9.2	3.4	3.4
Dracut	G	29	42.0	3.1	2.6
Fairhaven	G	21	12.0	21.7	21.7
Haverhill	S	17	16.8	1.4	1.4
Hingham	S & G	4 & 17	8.2	6.0	6.0
Ipswich	S	18	15.5	7.8	7.8
Kingston	G	11	11.5	20.3	20.3
Lawrence	S	14	12.3	4.2	4.2
Lincoln	S	8	3.0	5.5	5.5
Lowell	G	19	31.0	20.6	20.3
Marblehead	G	75	34.0	5.7	5.4
Marlborough	S	14	7.6	3.3	3.3
Methuen	G	30	28.0	2.9	2.7
Middleborough	G	23	17.5	41.4	41.4
Milford	S & G	11	10.5	15.2	15.2
Millbury	G	19	15.5	29.5	29.5
New Bedford	S	6	9.0	9.5	9.5
Newburyport	S & G	32 & 44	24.8	6.7	6.5
Newton	G	28	29.2	18.8	18.6
North Andover	S	14	14.0	1.4	1.4
North Easton	G	16†	10.0	3.4	23.4
Norwood	S	10	8.3	8.1	8.1
Palmer	S & G	7 & 18	10.5	5.0	5.0
Provincetown	G	12	3.9	37.4	37.4
Reading	G	49	63.0	16.4	15.6
Revere	S	13*	59.0	7.4	6.9
Sharon	G	39	27.0	15.1	14.8
South Hadley	S	7	8.7	6.0	6.0
Springfield	S	7	8.1	1.1	1.1
Stoughton	S	7	7.5	11.2	11.2
Wakefield	S	18	15.9	1.8	1.8
Waltham	G	36	37.3	29.3	28.9
Wellesley	G	39	16.0	19.8	19.8
West Brookfield	G	..	8.0	15.2	15.2
Weymouth	S	5	5.0	4.2	4.2
Winchester	S	13	8.5	1.3	1.3
Woburn	G	50	51.1	13.1	12.6
Wachusett Reservoir	S	9	8.4	1.3	1.3
Sudbury Reservoir	S	11	8.4	2.3	2.3
Lake Cochituate	S	19	18.3	1.8	1.8
Framingham Reservoir, No. 2	S	11	11.0	1.1	1.1
Framingham Reservoir, No. 3	S	12	8.8	1.3	1.3
Hopkinton Reservoir	S	9	7.5	3.9	3.9
Ashland Reservoir	S	9	6.9	3.2	3.2
Spot Pond	S	12	9.0	0.6	0.6
Jamaica Pond	S	..	29.0	0.0	0.0
Upper Mystic Lake	S	..	12.6	3.1	3.1
Lower Mystic Lake	S	..	34.9	0.4	0.2

* Metropolitan. † Easton.

Discussion.

Mr. Harrison P. Eddy.* I have been very much interested in Professor Whipple's presentation of the subject. I did not realize what the nature of his address was to be from the title of the paper, but I have had the privilege of discussing some of these subjects with him from time to time in the past few years, and I appreciate that he has done a great deal of very valuable work, which I believe will prove of interest and value as it is carried forward.

I wonder if one reason why water-works superintendents make so little use of the results of analyses is not because they are not in terms which are readily understood. A table of figures giving the results of chemical analyses is pretty dry reading. If there were some way by which the data could be put into popular terms, so that water-works superintendents would be able to visualize exactly what they mean more readily than they can at present, I think it might lead to very much greater use.

It seems to me that what the Professor says about the attractiveness of the water offers a field for development along that line. As that subject is given more attention, it seems to me that it will be possible to make reports in terms which are more popular, more easily understood, and perhaps more readily compared. The publication of results such as we have had in Massachusetts from year to year has been to a large extent useless to the general water-works superintendent. The consulting engineers have used them because they had to study details and make comparisons, not only for one supply at different times, but of general supplies and sources of supply. I do not feel therefore that the work that has been done has been lost or wasted, but rather that it might have been made more useful.

The diagrams which Professor Whipple has presented, if I understand him correctly, are made up from the records of these analyses, and if they could be visualized in some such happy manner as that, I am sure every water-works superintendent would be interested in the results. I hope that something of that kind may grow out of Professor Whipple's suggestions.

Mr. R. J. Thomas.† I would just like to say a word in regard to the water-works superintendents. In many of our cities they have no superintendent of water works. The water department is consolidated in what they call the Public Works Department, and generally the man in charge of the Public Works Department is not a water-works man, and frequently pays little attention to the water department. In these cities you will find that the water department is only a sub-department

* Of Metcalf & Eddy, Boston, Mass.

† Past President of the New England and the American Water Works Associations.

handled by a foreman, or perhaps two or three foremen, — according to the size, — one for pipe laying and others for various branches of the work. That tendency is growing in Massachusetts, and the water-works superintendent as we found him in the early days of this Association is disappearing, leaving no actual head (in many cases) of the water department, — certainly not a head who takes the interest in water-works problems and feels the responsibility they did in former days.

That may account for some of the failures to answer Professor Whipple's inquiries, and will no doubt in time make for inefficiency in the management and operation of water-works systems so controlled.

MR. M. N. BAKER.* I wonder if more interest might not be had by the water-works men, and perhaps by the city authorities as well, if more were done with bacterial results. It is not surprising that the ordinary tabulation of sanitary analyses of water should not arouse interest when presented to the water-works superintendents or to the citizens of a town. But if these were correlated with the vital statistics and the general health conditions of the city, and if they were brought to the attention, as they doubtless would be, of the local boards of health, some real use of the analyses might be expected. Certainly if the local boards of health are alive to their duty they will be deeply concerned with the right sort of analytical data on the character of the water, if accompanied with the right kind of interpretative comment.

That brings me to another thought that has been very much in my mind within the last few months, which is, whether, in view of the widespread diminution in typhoid, some other measure of the character of our water supplies and their effect upon the public health is not needed. This need has come very definitely to my mind in connection with the water supplies of Montclair, N. J., and Cambridge, Mass., to name only two places where there has within the past few years been considerable agitation over the character of the water supply, although both places are almost free from typhoid fever.

I am very much interested in this water from both the board of health and water-works viewpoints. I think that the board of health people and the water-works people, both in our cities and our technical associations, should put their heads together on this matter and see what the real significance of some of these things is, and whether we need some new measure of the sanitary quality of our water supplies.

Professor Whipple's paper, or that part of it which he has had time to read, is addressed very largely to the attractiveness of water. That I understand. But looking at it broadly, we can, if the subject is rightly presented, get money for water-works improvements if we can show, as we were able to show for very many years, that by a moderate expenditure the death rate of the city can be cut down.

* Associate Editor *Engineering News Record*, New York.

MR. GEORGE A. KING.* I would like to inquire if I rightly understood one sentence in Professor Whipple's paper. Speaking of the hydrogen ions and electrolysis, I understood him to say that the passage of electric current through the water pipe increased the electrolytic action.

PROFESSOR WHIPPLE. I think that is probably true. During the past year we have continued our experiments on the corrosion of pipe in the Sanitary Engineering Laboratory of the Harvard Engineering School. Among other things we placed pieces of wrought-iron pipe, with and without brass couplings attached, in tanks of flowing water, and noted the relative corrosion. Even the slight galvanic current set up by the two metals appeared to cause a more general corrosion of the iron than was observed in the iron pipe alone, not only at the joint but all along the pipe. It is my impression that with a current of electricity flowing through the pipe this action would be somewhat increased. These experiments are not completed. We wish to have them carried on for a year before much is said about them, but they are extremely interesting.

One of my colleagues in the University told me some time ago some interesting facts in connection with his studies for the detection of submarines. When a current of electricity was sent from one end of the steel ship to the other, not all of the current went through the metal of the ship; a small part of it went out through the water in a sort of arc to a distance of 25 ft., and a still smaller part went out into the water to distances of 100 ft., or more. That is, not all the current went through the ship, as one might think it would do. By arranging a delicate apparatus in the water he could detect these stray currents, and he used that principle in locating submarines during the war. If that is the case, it seems possible that there may be minute currents of electricity in the water between the brass fitting and the pipes which will be effective, at some more distant place than the junction, so that rusting may be caused a good many feet away from the joint as a result of having the two metals connected. Electrolytes in the water would hasten this action.

MR. KING. The passage of the current through the water increases the electrolytic action?

PROFESSOR WHIPPLE. Yes, and probably if a current of electricity is passed through the system the rusting will be faster.

MR. KING. Then would the grounding of telephone wires and electric-light wires have any effect?

PROFESSOR WHIPPLE. That is one of the very things we are trying to find out. We do not know definitely as yet. We are making quite a number of studies of this sort at Harvard. They require time, but I think that in the course of a year or two we shall be able to discuss a lot

* Superintendent of Water Works, Taunton, Mass.

of those questions more intelligently than now and bring the results to the attention of the members of this Association.

MR. STEPHEN DEM. GAGE.* I have been very much interested in this paper, because for a number of years I have been trying to work out some satisfactory method of bringing home to the people the differences in our public water supplies.

As Mr. Thomas has brought out, a good many of the men who are nominally in charge of water works are not water-works men, and are mainly interested in seeing that the works are kept in operation at reasonable expense and that the necessary funds are obtained for this purpose from one source or another. So long as the state department of health passes their water as of safe quality they are very likely to consider that the supply is plenty good enough for all practical purposes.

It has seemed to me that if we are to raise the standard of many of our supplies, we will have to arouse and unite the sentiment of the people in the individual communities. One way to do this is to bring home to the people the fact that they are not getting as good a water as the people of some other community. Oftentimes the thoughtless water-works official can be brought to see the light in the same way, but unless he has public opinion behind him, he may not be able to get very far.

In the supervision of our various water filter plants in Rhode Island we are using this method to a certain extent. When we make our regular visit to a plant, if we find that the operating results are not as good as they might be, we tell the operator that John Smith at B—— plant is making better water, or is operating at a lower cost. He has visited John Smith's plant and knows that his own equipment is as good as Smith's, and his pride leads him to try to beat the other fellow.

I have a feeling that we might be able to accomplish something by working along the same lines with our unfiltered water supplies, if we had some simple system of grading such as Professor Whipple has outlined. If, for example, it were generally known that the water of one community was very much better than that of another, the people of the first place would be very likely to brag about it and thus perhaps arouse the citizens of the second community to support needed improvements in their own supply.

Some years ago I had large bottles of water from our different water supplies on exhibition at the various county fairs, with placards commenting on the varying character of the water, the effect of filtration, etc. This exhibit aroused considerable interest and many of our visitors stopped to ask questions, and most of them were intelligent questions. We felt that the educational value of these exhibits was sufficiently great to warrant us in repeating them for two or three years.

One incident occurred at one of the fairs, however, which illustrates the fact that there is another side to the question. Early in the afternoon

* Chemist and Sanitary Engineer, Rhode Island State Dept. Health.

a woman came up and said, "What is the matter with the Westerly water? I have just moved to Westerly from Woonsocket, and we can't drink the water, it has such a funny taste." The Woonsocket water is a surface water that ranges in color from 40 to 90 or more, and usually has a distinct vegetable odor, while the Westerly water is a clear, colorless, ground water with no taste or odor. I had always considered the Westerly water one of the best and most attractive waters in the state, while the Woonsocket supply wouldn't rank very high according to Professor Whipple's method of scoring. But this party had learned to like the dark-brown water, and the clean ground water tasted flat to her. Perhaps this serves to explain why it is sometimes so difficult to arouse popular sentiment in favor of improvements in some of our public water supplies. The people have learned to like them, bad as we sanitary engineers may think they are.

I should like to ask Professor Whipple one question. On what basis did he grade the odors of the Massachusetts supplies? Was it on the basis of the observed odors of laboratory samples, on the basis of counts of micro-organisms, or on the basis of complaints from consumers?

PROFESSOR WHIPPLE. On the observed odors. We found it was not possible to do it on the basis of the microscopic organisms because the State Department of Public Health records are kept in absolute numbers of organisms, taking no account of their size.

THE ECONOMY OF HIGH INITIAL COST AND EXTREME CARE IN SERVICE-PIPE INSTALLATION.

BY REEVES J. NEWSOM.*

[*Read September 14, 1921.*]

In cities and towns where the pressures vary between 35 lb. and 55 lb. in the major portions of the residential districts, the cleaning of service pipes to insure satisfactory force of water is apt to be a serious problem.

For the past ten years the number requiring cleaning in Lynn has been upwards of 2 000 per year, and has approximated 20 per cent. of the domestic services. The cost of this work varies from about $1 to $5 per job, depending on the accessibility and layout of the service, and averages around $2. To this must be added something for services which are made to leak when disturbed, while otherwise they might serve for several additional years.

This means on the average an expenditure of $10 and upwards in twenty-five years for the cleaning of each service pipe, and, what is of almost equal if not greater importance, there are five periods of more or less duration prior to each cleaning when the water service is unsatisfactory to the consumer, and when great inroads are necessarily made on the goodwill of the public towards the Water Department, — something which should at all times be cultivated and guarded rather than injured or destroyed. The annoyance to the consumer is made more acute by the fact that inasmuch as the majority of these complaints are made with the beginning of the hot weather, and the lawn-sprinkling season, they come piling in at the rate of 25, 50, 75, or even 100 a day, and soon we find ourselves three or four weeks behind, and it is an exceptional consumer who will wait that long without feeling that he has a real grievance and that he is being discriminated against.

The coming use of the flush valve instead of tanks as bathroom equipment but serves to make more frequent and serious the lack of sufficient pressure.

In view of these things we have come to believe that a somewhat larger original investment and the use of extreme care in making service installations is not only economical in the end but good policy as well. We have, therefore, taken two definite steps to relieve the situation, first by increasing the size of service pipes for a given installation, and second by making it practically impossible for the water to come in contact with iron at any point from the main to the tee inside the cellar wall.

* Commissioner of Water Supply, Lynn, Mass.

Years ago hundreds of ¾-in. services were installed, in some cases for as large as three-family houses, and many of these are still in use. In recent years a 1-in. service with a ¾-in. corporation cock and gooseneck has been the ordinary size installed, but we have now gone a step farther and use this size only for cottage houses not over 30 ft. from the main, and for all ordinary installations and renewals we use 1¼-in. pipe with a 1-in. corporation and gooseneck. This size we believe will give ample water for all reasonable uses, and our next care has been to insure the maintenance of this full size for a long term of years.

We use wrought-iron service pipe, and line it with cement. The common difficulty of a non-concentric lining has been overcome by certain special features of the cones used for shaping the cement. We now use a single cone of more than the ordinary length, the last six or eight inches of which is $\frac{1}{16}$ in. larger than the front section. Two sets of spring steel wings are provided, one near the forward end and one slightly back of the middle, which centers the cone rigidly. The enlarged part of the cone smooths out and fills in the grooves made by the wings, and because it is attached to the remainder of the cone it cannot drop, due to its weight, as does the ordinary follower.

Cement-lined service pipes were used by the department from 1871 to 1890, and many of these pipes are still in service. They were installed, however, with unlined fittings, and it has been necessary to take them up, due to plugging of the latter. In all cases the pipe taken out, even after forty years' use, is in good shape, and the inside is as clean and smooth as the day it was installed. We have learned, therefore, that it is in the connections that the trouble develops, and that it is here that we must exercise our greatest care.

Beginning at the main, the first precaution is to prevent the stoppage of the corporation, and our method is to use cocks which have an extension beyond the threaded portion entering the main, about ¾ in. in length, which is similar to the old eel guard, except that it is solid rather than slotted, and is open full size at the end. This measure is especially valuable for tappings in 12-in. pipes and above, where the thickness of iron prevents any appreciable part of the cock from protruding through the main. This type of corporation makes it necessary for the rust action taking place where the drill has broken through the cast iron and destroyed the coating to pile up nearly an inch thick before it begins to close over the end of the cock, and usually, due to the slowness of the action when the iron is partially covered with rust, this will require a very long time.

Where the joints are made in the service line there are two opportunities for rust formation, the cut end of the pipe and the breaking back of the cement lining if the pipe is cut with an ordinary pipe cutter.

If the cut end of pipe is exposed in the couplings, only ordinary rust action takes place, but if it is exposed in the brass fittings, very much more rapid galvanic action takes place, due to the presence of brass, iron, and

water, the latter always containing enough salts to make it an electrolyte. We line our couplings, tees, elbows, and forty-fives with lead, and also put a ring of the same material in the female solder nipples in the end of the goosenecks and in the curb cocks.

The solder nipples are tapered, which allows entering a tool part way, until it strikes the side of the fitting and prevents the lead going through when it is poured. The making of the lead ring in the curb cocks is greatly simplified, and the cost of this work is more than paid for by using a cock one size smaller than the pipe, with enlarged outlets. For example, for use with $1\frac{1}{4}$-in. pipe a 1-in. curb cock with $1\frac{1}{4}$-in. outlets is used, which gives a shoulder against which the inside lining tool is held. This tool has a flat tapered end, which allows a tight fit against the shoulder and prevents any lead from going through when poured. The cocks so used are substantially the same size as the larger-sized pipe when lined and give plenty of waterway, for, when the formation of rust is precluded, the need of a large, roomy curb cock disappears.

The bushings used for the lining of all fittings are carefully regulated so that they screw in only five or six threads, which assures the pipe coming solidly in contact with the lead, so that the raw iron will be completely covered. To insure a tight fit between the lead and cement, the inner half of the inside end of the bushing is beveled outward on a 30° angle, so that the cement and lead come in contact slightly in advance of the iron and lead.

The final precaution is to prevent the cement from breaking when the pipe is cut, so that the last opportunity for the contact of water with iron will have been taken care of. This is done by cutting all pipe in the shop by a metal cutting machine which, to all appearances, is a power hack saw, made with heavy accurately ground bearings, and which gives an absolutely square end to the cement as well as to the iron.

This is accomplished by having a man from the engineering department follow up the service gangs a couple of hours after they start digging for an installation, and take measurements of what will be required for each job. These measurements not only serve the engineering department in making the records, but are immediately turned in to the stock department and the pipe and fittings are gotten out and are partially made up. A little later the trucks taking care of the service gangs return to the shop and deliver the material to the jobs, where it is slipped into place.

The additional cost of services so laid is, on the average, approximately $5.50, made up as follows:

Larger corporation	$0.75
Larger gooseneck	1.25
Larger curb cock	.85
Larger pipe, 6c. per ft.	2.40
3 lead rings in brass fittings	.25
	$5.50

The finished product compares favorably with either lead or brass for longevity, and at very much less cost.

It is our firm belief that all these things, some of which may seem more or less superfluous, are fully justified, especially in cities where pressures are relatively low. It is only to be regretted that those to benefit most will be the water-works officials twenty to thirty years hence, while at present we must continue to take the criticism of the dissatisfied consumers and to dig up well-paved streets to remove pipes which were installed in the past with less care than we now exercise.

Discussion.

Mr. J. M. Diven.* How is the outside of the wrought-iron pipe — or wrought-steel, I suppose probably it is — protected? Is it also covered with cement?

Mr. Newsom. We use wrought-iron pipe, not steel, and do not put any protection on the outside of the pipe, but use ordinary black pipe, except where it is to be laid in a part of the city where we encounter salt water, in which case we use galvanized pipe. When we buy galvanized pipe, we buy it galvanized on the outside only, so that there will be no likelihood of any irregularities inside the pipe to interfere with the proper lining with cement. The pipe I spoke of as having lasted forty years or more in the ground was only ordinary black pipe.

Mr. Diven. What does it cost per foot to line 1¼-in. pipe?

Mr. Newsom. Between 2½ and 3c. a foot for 1¼-in. pipe.

Mr. Diven. Would you recommend using cement-lined where the pressures are high as well as where they are low?

Mr. Newsom. I think the advisability of using cement-lined pipe is entirely independent of the pressure.

Mr. David A. Heffernan.† Mr. Newsom and I have corresponded relative to the lining of pipe. I have been lining wrought-iron pipe with cement for more than a dozen years. This was a good plan as far as it went. The brass fittings used in connection with a wrought-iron service generated a galvanic current, so that it became necessary early this year to line all fittings from main to meter where they are made on to the iron pipe, thus preventing the brass from coming in contact with the iron at any point where the water would reach them. This makes more work and a more expensive service, but I can see no other way of overcoming the troubles we are meeting, and it is my confident belief that those superintendents who adopt this policy will not regret it.

Mr. J. E. Garrett.‡ I should like to ask Mr. Newsom if he uses reamed pipe, or ordinary black pipe unreamed, and if with the special

* Secretary, American Water Works Association.
† Superintendent, Water Works, Milton, Mass.
‡ Civil Engineer, Stamford, Conn.

lining cones that he has it is unnecessary to ream the pipes before lining them?

MR. NEWSOM. No; the cones will not take care of irregularities in unreamed pipe. We use short lengths, — that is 14- to 16-ft. lengths of black, reamed pipe. It has been our experience that even when you buy black, reamed pipe there are certain irregularities in that pipe which cause trouble when you use solid wings, but not with spring steel wings.

MR. CARLETON E. DAVIS.* You spoke of the larger-sized pipe. Is the service charge based on the size of the pipe?

MR. NEWSOM. I regret to say that we have not gotten quite into that stage of charging yet. We do not have a service charge.

MR. DAVIS. But this service pipe does not affect the charge for water?

MR. NEWSOM. At the present time it does not. It probably would if we were figuring it just that way, although I believe that the amount saved in cleaning the pipes will be more than the cost of putting those pipes in this way, so that we will not require any more revenue than we have now. It is simply spending it in a different way.

MR. DIVEN. What is the method of cleaning the pipe?

MR. NEWSOM. We use the ordinary methods in cleaning. We either insert rods with cutters on the ends of them, or else we in some cases use hollow tin tubing, the same as is used for thawing pipe. That is simply run in and out. When we get to the corporation cock and find that stopped up so that we can't push in a reaming tool there, we use an instrument which we call a spudger, which is a section of brass pipe which we secure to the end of the service pipe in the cellar. Into that we fit a wooden plug which will just slip into the brass pipe. We then turn on the pressure, allowing the spudger to fill, meantime holding the water back with the wooden plug. The latter is then hit with a hammer, which causes water hammer and drives any obstruction out of the corporation cock.

MR. R. H. ELLIS.† I would like to ask Mr. Newsom if in his experience with cement-lined pipe he has ever found any trouble with the cement cracking or pulling inside of the pipe, provided a heavy fill has been put on top of the pipe, causing a slight sag, or something of that nature. My reason for asking is that in our department at North Andover we are busily engaged at the present time in removing practically all the cement-lined pipe that we have, owing to the fact that the cement has scaled off, allowing corrosion to set in in the interior of the pipe.

MR. NEWSOM. I have never had any experience of that kind. I am inclined to believe that if the cement peeled off, or cracked off, due to nothing more than simply a sagging in the pipe, it was improper construction when the pipe was originally lined, because our experience has been that pipe properly lined can even be bent around a small angle without

---

* Chief Bureau of Water, Philadelphia, Pa.

† Superintendent, Board of Public Works, North Andover, Mass.

injuring the cement. While we do not do that as a matter of practice, it certainly is more severe than a sag in the pipe would be.

MR. BERTRAM BREWER.* When the speaker was in Waltham and in charge of the water department, one of the things that came up was the question of the use of cement-lined pipe. In the years gone by it had been used to a great extent, but suddenly, without apparent reason, those in charge gave it up and began using plain galvanized pipe instead. An investigation of the situation with some of the foremen who were directly concerned with the work disclosed the fact that, just as Mr. Newsom's paper suggests, the work had been very carelessly done and some of the cement lining had separated from the iron and the pipe had become plugged. It proved to be very unwise to give up the use of cement-lined pipe, especially in Waltham, so we began using it again with more skill and found no difficulty in getting a permanent lining.

While I am on my feet I just want to say that I do not know of any literature that contains more valuable information on this general subject than the volumes of the New England Water Works Association JOURNAL. A Committee on Service Pipes made a valuable report, a few years ago, published in the September number of Vol. XXXI.

I do not think that there is proper realization of the fact that carbonic acid is extremely deleterious to metal, on account of its corrosive action. In Massachusetts many of the ground-water supplies contain carbonic acid, particularly such water as that of the Cook wells in Lowell, the Waltham water, the Newton water, and many others. No one should think of laying connections where there is carbonic acid in the water unless cement-lined pipe is used or some equally good protection is secured as that provided by the cement.

MR. GEORGE A. KING.† I should like to ask Mr. Newsom if he has ever used what I call the Boston plan of cleaning, — using a force pump to drive paper through the pipes?

MR. NEWSOM. No, I have never used that. We have had success with the method we have used and have found it very effective.

MR. BREWER. I have tried out the paper-plug method of cleaning old services very thoroughly and should say in over half of the cases where it was tried success followed the attempt.

MR. TIMOTHY W. GOOD.‡ I am very much interested in Mr. Newsom's paper. I want to say, for the benefit of the members, that in the city of Cambridge, Mass., with approximately 18 000 services, we believe in a proper method of lining on original installations. We have used nothing but lead-lined pipe for the past fourteen years, and have never had any trouble, except that at times you might get slight corrosion at the main where the corporation cock is tapped in; this, however, is easily remedied

* Assistant Engineer, Massachusetts State Department of Public Health.
† Superintendent, Water Works, Taunton, Mass.
‡ Superintendent, Water Works, Cambridge, Mass.

by means of our cleaning rods. We are firm believers in rigid connections at the main. We put a coupling right on the corporation cock, and our experience has shown that you get sufficient expansion through the basement wall, and the least number of joints you have out under the pavement the better it is for the service. We consider the added cost of lead-lined pipe a good investment. In fourteen years we have never had to renew, and we know that we will go fourteen years more.

MR. GORDON Z. SMITH.* I should like to state that I had lately an experience in a little town in this state in cleaning out various kinds of services, except lead pipe. There are no lead services there. Some years ago the department manufactured cement-lined pipe of their own, and at the joints there was a brass thimble inserted. The joint itself was a regular iron-pipe joint. After some years those cement-lined services did fill up, particularly at the corporation connection and at the curb box and at each joint. The water department installed the service from the water main to the curb box, so that we were responsible for it and its renewal. Some time in 1914 I discovered the method that was being used in Boston in cleaning out services with the use of a force pump and a wad of tissue paper. It worked out very successfully in most instances, even with cement-lined pipe. I have had curb cocks so filled up that one couldn't see any light through them, they were absolutely filled full, and those were cleaned out as good as new. But where the pipe lining had broken and the pipe had tuberculated along in the middle of its length, we couldn't do anything in cleaning that out, because it was something that the paper would not handle. If it did, there would so much get ahead of the paper wad that the pipe would be absolutely plugged. We had some three years' experience with it while I was there, and it saved us quite a little money in the renewal of services.

MR. W. C. HAWLEY.† I am wondering if a part of our service-pipe trouble is not due to the use of zinc in the mixture of which our corporation cocks and curb cocks are made. I came to the conclusion, a good many years ago, that it would be better to have a mixture 88–10–2, the two per cent. being of lead. It makes it a little harder to machine, but I think it is better than a mixture containing zinc.

MR. DIVEN. You better bring that before the Committee on Fittings.

MR. LINCOLN VAN GILDER.‡ Our own experience has been that standard galvanized pipe for services, or a ¾-in. pipe, will close up in about ten years, and that the same pipe with lead lining lasts indefinitely. We have never used the cement, and that is something I have no personal knowledge of. We sometimes have difficulty with a corporation cock or a curb cock.

---

* Chief Inspector, Bridgeport Hydraulic Company (Conn.).
† Chief Engineer, Pennsylvania Water Company.
‡ Superintendent, Water Works, Atlantic City, N. J.

MONEL METAL AND ITS SUITABILITY FOR WATER-WORKS USE.

BY H. S. ARNOLD.*

[*Read September 14, 1921.*]

Monel metal, a natural alloy of nickel and copper produced by the International Nickel Company, is attracting considerable attention in engineering circles because of its peculiar properties which make its field of usefulness very broad.

Since Monel metal has been termed a natural alloy, and since to many its history is obscure, I will describe briefly the source of supply and method of manufacture.

Monel metal comes from an ore of nickel and copper occuring in the Sudbury district of Ontario, Canada. The ore deposits of this district constitute the largest known commercial nickel deposits in the world. The Creighton Mine, one of the International Nickel Company's properties, is the largest producing nickel mine in the world. The ore as mined contains considerable sulphur. By heap roasting, about half of this sulphur is eliminated. The roasted ore is smelted in blast furnaces to a matte containing about 25 per cent. nickel and copper. This matte is blown in Bessemer converters to approximately eighty per cent. nickel and copper. The converter product, called "Bessemer matte," is shipped to the Company's New Jersey refinery, where it is pulverized, dead roasted to remove sulphur, and finally reduced with charcoal in oil-fired reverboratory furnaces to Monel metal.

The furnaces are tapped at about 2850° F., and after deoxidizing in the ladle with manganese and magnesium, the metal is chill cast into ingots for rolling and forging or into blocks for remelting purposes. Monel for sheet rolling and for remelting carries about $\frac{1}{4}$ per cent. manganese, while for rods, forgings, wire, etc., the manganese is raised to $2\frac{1}{2}$ per cent. Metal for sand castings usually has about 1 per cent. silicon added. The alloy, Monel metal, thus produced contains approximately 67 per cent. nickel, 28 per cent. copper and 5 per cent. other metals, chiefly iron, manganese, and silicon.

It is a single solid solution which looks and in general acts like a pure metal. There has been no separation nor any addition of nickel or copper during the refining process. The nickel-copper ratio remains the same from ore to finished metal, hence the name "natural alloy."

---

* Of the International Nickel Company, New York.

Monel can be cast, forged, hot rolled, or cold drawn. It may be autogenously welded, brazed, soldered, stamped, machined, and polished. It is annealed by heating to 900° C. It is hardened only by cold work.

Physical Properties.

In its physical properties it resembles medium steel to a certain extent. Its tensile strength forged or rolled runs from 75 000 to over 100 000 lb. per square inch, depending on the amount of work and the finishing temperature. The elastic limit will be from 40 000 to 75 000 lb. per square inch, elongation 30 to 50 per cent. in two inches, reduction of area 50 to 70 per cent. It is comparable to an annealed medium steel in hardness, its Brinell numbers running from 145 to 170. The Shore scleroscope hardness is about 27. The yield point under compression runs from 60 000 to 70 000 lb. per square inch.

Values for the torsional strength of hot-rolled Monel metal are yield point 50 000 to 80 000 lb. per square inch, maximum stress 75 000 to 90 000 lb. per square inch. Shear tests give, for double shear, 90 000 to 127 000 lb.; for single shear, 45 500 to 60 000 lb. per square inch. A research laboratory (G. and J. Weir, Limited, Cathcart, Scotland) has recently made an interesting series of comparative Izod impact tests on several different metals, and the position of Monel metal at the top of this list is worthy of comment. The metals thus compared were: Three-quarter inch rolled mild steel rod, wrought iron, rolled brass rod, forged copper, rolled Monel metal rod, cast admiralty gunmetal, iron cast in green sand, and high-tension bronze cast in chill. The results are expressed in foot-pounds absorbed in breaking or bending, and follow in the order of their magnitude.

Cast iron	.08
Admiralty metal	8.0
Rolled brass	23.0
High-tension bronze	25.5
Forged copper	46.0
Wrought iron	58.4
Mild steel	76.7
Monel metal	113.7

All pieces were broken in the test except copper, wrought iron, mild steel, and Monel metal. Tests at the Bureau of Standards in Washington verify these figures and give Monel metal a higher figure than heat-treated alloy steels of twice its tensile strength. This high value for the resistance to impact seems a matter of course to one who has seen Monel metal parts subjected to sudden severe shocks which would be destructive to other metals of the same strength, for in these cases they have seen Monel metal only bent or distorted in such a manner as to require straightening to be again put into service, while the other metals of similar or greater tensile strength were broken and ruined for further use. There was an interesting

illustration of this some time ago, on a destroyer which came into a navy yard with one of its turbines out of commission. Examination revealed the fact that a nickel steel bucket had snapped when revolving at high speed, and before the turbine was shut down all the other steel buckets were broken off short. None of the Monel metal buckets were broken, in spite of the fact that steel buckets were wedged in among them in such a way as to bend them badly. It was necessary to replace the steel buckets with new ones, while those of Monel metal needed only to be straightened.

The modulus of elasticity is about 25 000 000, about the same as wrought iron and twice as great as brass. This comparatively large value has bearing in the construction of such pieces of apparatus as propellers, where distortion may cause a great loss in efficiency.

The ultimate strength of sand-cast Monel metal is about 75 000 lb. per square inch, yield point 40 000 lb. per square inch, elongation 30 per cent. in two inches.

The hardness is about 20 Shore, 100 Brinell.

The tensile properties of cold-drawn or rolled wire, rod, or strip, vary largely according to the cold work, degree of annealing and gage. The ultimate strength may be produced from 85 000 to 160 000 lb. per square inch, yield point 50 000 to 100 000, elongation 30 per cent. to 1 per cent., depending on the hardness, which may be as high as 45 Shore when heavily worked and not annealed. When annealed, the hardness may be as low as that of hot-rolled material.

The melting point of Monel metal is 2480° F., its specific gravity 8.87 cast and 8.98 rolled, — 14 per cent. greater than steel. Its coefficient of expansion between 70 and 212 F. is .00000765 per degree, 15 per cent. greater than steel and 18 per cent. less than copper. Its electrical resistance is 256 ohms per million feet and temperature coefficient .0011 per degree Fahrenheit. Its relative heat conductivity is one fifteenth that of copper. The amount of shrinkage in cooling from the molten state is $\frac{1}{4}$ in. per foot.

Monel metal is, perhaps, the best general metal for resisting acid, alkalies, and general chemical corrosion. There are other metals, of course, which are more resistant to certain corrosive agents, but Monel metal, whose solution potential is well below hydrogen and acid resisting metals, is in general attacked less seriously than any other metal. It combines with its slow rate of corrosion the property of corroding evenly with little pitting or local attack.

It withstands successfully such corrosive actions as that of atmospheric conditions, fresh or salt water, wet or superheated steam, gases of combustion, metallic mercury, and the oxidizing influence of heat up to 1 000° Fahrenheit, below which point only superficial oxidation takes place. It has been shown by experiment that benzoic, citric, hydrofluoric, lactic, dilute phosphoric, picric (in the cold), salycilic, tannic, hydrocyanic acids, and carbolic acid have practically no effect on the metal. The evidence seems sufficient that it is resistant to all fruits and fatty acids

and phenols. The action of foods is not severe on Monel metal, and food may stand in vessels of it for some time without acquiring a foreign flavor. Tomatoes and clams are exceptions to this. They have been found at times to be so affected by long standing in Monel metal as to make them unfit for use.

Pure alkalies will, in general, attack Monel metal only very slightly. Some cases have been known, however, where alkalies in the presence of their salts have affected the metal, and it may be stated as a general rule that such mixtures will produce definite corrosion.

Principal Types of Uses and Related Properties.

One general type of use is for structural purposes where it is subjected to severe weather conditions. This includes its use for roofing sheets, skylight frames, window screens, etc. The properties which enter here are its resistance to weather corrosion and its strength. An example of this use is the roof of the Pennsylvania Terminal, New York City, which is entirely of Monel metal and which has needed only minor repairs since it was built. Even the minor repairs have been caused by faulty laying, and not by any failure of the metal. Another is that of Monel metal screening which has recently been removed from the summer home of an officer of the Nickel Company, on the Jersey coast, after nine years of service exposed to weather and spray carrying sea breezes, winter and summer. When, after this period, it was removed for examination and exhibition it showed little signs of wear or corrosion. This service has been estimated to be equivalent to twenty-five years of such service as ordinary screening receives when only in use during the summer.

Another general type of use is for household, hotel, and hospital hardware, including trimming and fixtures where a bright permanent white polish is desired, other hardware, plumbing parts, cooking and serving utensils, table flat ware, washing machines. These uses require that the metal be resistant to the action of foods, hot and cold, and to cleansing agents, also that it take and retain a good polish.

In regard to its use in superheated and wet steam and hot water, some very interesting data have been presented to the Engineers Society of Western Pennsylvania by J. Roy Tanner and George J. Stewart. Monel metal has given good service in valve seats, rings, bushings and stems, pump rods and plungers, meter parts, stop cocks, etc. The important properties here are the retention of tensile strength at high temperatures, similarity in tensile and expansion qualities to steel, and tendency to wear or corrode evenly if at all.

Its resistance to oxidation and to gases of combustion at moderate temperatures makes it serviceable in oil combustion parts, spray valves, ignition points, welding torch heads, conveyors and stirrers for furnaces, internal combustion engine valves, glass rollers, and blowpipes.

Being resistant to many forms of chemical corrosion and at the same time of high tensile strength, impact- and wear-resisting properties, it is used in chemical work such as pickling crates, pins, tie-rods, nuts and washers, evaporating and drying pans, fourdriniers, filter cloth, textile machinery, general acid and chemical handling work.

Some Special Uses and the Related Properties.

Of particular interest in the Pittsburgh district is the use of Monel metal parts in the process of pickling steel sheets and slabs in sulfuric acid. The metallic equipment of this work consists of crates, pins, hooks and bales, tank tie-rods, nuts and washers, and tank drains. The original cost of Monel metal for this work is greater than that of most of the anti-acid bronzes which are used for the same purpose. However, the greater resistance of Monel metal to the acids and pickling agents, combined with its strength and resistance to impact and its amenability to re-working, make it cheaper in the final analysis.

If Monel metal is to be used where exposed to hydrochloric acid or its fumes, it should be subjected to a preliminary trial, as it has been found that in some cases it will not stand up, while in others it withstands the action of the acid with entire satisfaction. The laws governing this action have not been thoroughly worked out. It is evident that local conditions and methods of handling have a great deal to do with its ability to resist this acid. It is probably true that Monel metal will resist it, however, better than any other common alloy. In no case is it recommended for nitric, chromic, perchloric, hot picric, or phosphric acids, or such oxidizing salts as ferric sulfate, copper sulphate, mercuric chloride, or molten zinc salts. Neither will it resist molten metals or molten sulfur.

It resists well the action of dry chlorine and sulfur gases.

Another important special use of Monel metal is in turbine buckets, especially for marine turbines where, the pitching and tossing and twisting of boats in a heavy seaway, operating contrary to the gyroscope action caused by the high speed of the moving parts, sets up strains and stresses which would cause other metals to crystallize and snap off, Monel metal remains unaffected. Another factor in its favor for this work is its ability to retain a large percentage of its tensile strength and other properties at the temperature of the steam operating the turbines.

In power plants its ability to retain tensile strength at steam temperatures and to resist the erosion of live steam give it a large use. Valve trim and turbine shrouding are often made of it. Pump rods and liners in pumps that handle water containing a large amount of acid or other corrosive agents are generally of Monel metal. In hydroelectric power plants large impellers cast of Monel metal are often specified. In the latter case bronze has been discarded because the erosion of the water eats away and roughens the vanes. Monel metal is admirably suited to replace it because of its property under such erosive action, instead of becoming pitted and

roughened, of remaining bright and smooth, thereby giving maximum efficiency.

Several years ago, Brezowsky and Spring of the Crane Company conducted experiments comparing Monel metal to other alloys for use in valves made by the Crane Company for handling steam. All of these tests showed that Monel metal was better suited for their purpose than the other metals tested. It retained its physical properties better than practically any other alloy, and where this was not the case the difference was very slight. Its strength was either greater at corresponding temperatures due to its greater initial strength or it was more resistant to the corrosive and erosive properties of the superheated steam. These properties have been more recently checked in the laboratory of the International Nickel Company and in laboratories abroad. Tanner and Stewart in their paper showed that for handling superheated steam the only satisfactory valve was one of cast-steel body with Monel metal mountings. It has been repeatedly compared with other alloys for this work and none has so far been found to approach it.

Its heat-resisting qualities, while not as good as nichrome or chromel, or pure manganese nickel, are such as to make it well suited for certain heat-resisting uses. It has been found, for instance, that Monel metal exhaust valves in internal combustion engines give excellent results.

In the mining industry, Monel metal is found well distributed in the form of pump rods and liners, mine screens, and coal chutes. In the latter case its ability to resist abrasion as well as corrosion have been the factors governing its selection. At the same time Monel metal should not be used in mines which have an appreciable amount of ferric sulfate in the water, as this salt has a decided corrosive action on it.

The ability of Monel metal to withstand the action of weak acids and other corrosive agents of foods gives it value in the handling and preparation of food products. Packing-house equipment which comes in contact with brine and salt is largely made of it. Meat and fruit slicing machines, canning apparatus, dairy machinery such as butter handling machines, milking machines, separators and pasteurizers, have parts of this metal. In the kitchens of some of the large, new, up-to-date hotels, Monel metal is prominent in the form of steam table-tops, coffee urns, pots, and pans.

A growing use of Monel metal for direct personal interest to many is as a metal for the manufacture of golf club heads. The use of Monel metal does away with the necessity for grinding and polishing to keep the clubs bright, and the clubs will therefore not become lighter with use. Being of as great resilience as steel and slightly higher in specific gravity, Monel metal heads give a somewhat greater distance to the ball.

Experiments are being conducted in New York City to determine the suitability of Monel metal for parts in telephone and telegraph subways. Here the metal parts are subjected to seepage from the sewers and the filthy salt water that often fills the subways along the water front. These waters are exceedingly corrosive. Ladders for the manholes, locks for the

covers, and similar parts have been made of Monel metal for trial. To date these parts have been in service nearly two years in the worst manhole in the city and are as good as when put in, while parts made of other metals have lasted, at best, only a few months.

Some of the other interesting places where Monel metal serves a special purpose, which are too numerous to discuss in any detail, may be mentioned as: Parts for ordnance and for submarine construction, incinerator machinery, sewage handling machinery, lavatories, textile machinery, storage battery casings, burning points and racks for enamel ware, plugs and other parts in the manufacture of gasoline in Burton stills, oil-handling machinery, parts of tempering furnaces, tank linings for acid and alkali, gas-engine water jackets, chain to resist weathering, wire rope, sash cord, resistance wire, rivets and nails, dyeing machinery, refrigerating machinery, and sugar-refining equipment.

So far I have not dealt directly with the suitability of Monel metal for water-works uses.

That Monel metal is worthy of consideration by water-works engineers is evidenced by its present use in this field.

Monel metal is in constant demand for the gear parts in water meters, especially in the middle west and on the Pacific coast.

Monel metal pump-liners, pump rods, valves and valve stems have excellent records of service dating back to 1907. The Boston Fire Department installed Monel metal valve stems in the high-pressure fire hydrants in 1909. The results have been very satisfactory.

Monel metal has been used to replace bronze anchor bolts on the Ashokan Dam. It also finds use in filter screens, and in water purification system. Chlorination parts, namely, valve stems and seats, have been standard for the past eight years.

The field is one in which we have not gone deeply, yet it would appear from a general survey that the opportunities for Monel metal are large. It is here, perhaps, that the non-corrosive properties of Monel metal will be of primary interest. We have become less and less confident of our ability to theorize about the behavior of metals toward corrosion under actual service conditions, and realize that corrosion tests to be of practical value must be made in the field or at least upon a comparable scale. Yet it is appreciated that the use of any particular metal is rarely based upon the sole property of the resistance to corrosion. In fact, I venture the assertion that resistance to corrosion alone, although a necessary factor, is quite frequently not the determining one of practical serviceability in any particular " anti-corrosion " piece of construction, but some other property often entirely unrelated to it. As a corollary to this, I can state from my own experience that materials may be sufficiently resistant to corrosion for jobs requiring this property, but their actual use for it is quite out of the question on account of their failure in other and quite different directions. The engineer is greatly in need of a material of corrosion-resisting proper-

ties which, in addition, is otherwise well balanced in its physical characteristics and without serious deficiencies. It must be readily subject to the usual processes of fabrication; welding, soldering, forging, casting, machining, rolling, drawing, stamping, etc. It is in this respect that most specialized corrosion-resistant metals display inability to meet requirements without expensive and troublesome changes of design.

Finally, a material to be generally useful must be available in commercial forms. The importance of this qualification will be fully appreciated by all those familiar with commercial development of any sort.

Discussion.

Mr. J. M. Diven.* Has this metal been used by the valve manufacturers for valve stems? If so, about what additional cost would there be over bronze metal?

Mr. Arnold. Practically all of the large valve manufacturers are well acquainted with Monel, but they have given their fullest attention to steam valves. The Crane Company, however, has made some large valves for water-works uses.

The high-pressure valves previously mentioned were made for the Boston Fire Department by another manufacturer, hence we have no record of costs. In general, Monel castings will cost about twice as much as bronze, and fabricated Monel about two thirds more than bronze.

Mr. Carleton E. Davis.† Is that cost on a pound per pound basis, or is it allowed for smaller size but possessing greater strength?

Mr. Arnold. Pound per pound. There is, of course, quite a chance to make a saving in size, providing you want to do it. It is usually a case where for safety we take advantage of a stronger material rather than cut down, although I know the latter is done in many cases. For instance, in meter parts, I believe they are cutting down. In casings and the like, they cut down considerably, from a cast to forged material. Where they have found it practicable to use a stamped or forged material to replace a casting, they have been very successful in cutting down weight.

Mr. William Ross. I would like to ask whether your company will sell pig now. I asked some time ago, and they would not sell pig but would sell castings; but for experimental purposes that was not very practicable.

Mr. Arnold. No, there is no objection at all to that. They will be glad to sell either in the form of 50-lb. pigs or in the form of shot.

If you have any difficulty I will be very glad to have you write to me personally.

Mr. Diven. I do not think the water-works operator would hesitate to pay twice, or several times, the cost of a valve stem, if he could get a valve stem that would not give out.

---

* Secretary American Water Works Association.

† Chief, Bureau Water, Philadelphia, Pa.

MR. SAMUEL E. KILLAM.* I might say that last year, on one of our hydraulic valves, we were unfortunate enough to allow it to freeze, and it cracked the cylinder. It was a case of replacing that cylinder. I was very much surprised, when the foreman took the cylinder off, to have him report that the valve stem came out. It was 88–10–2. And later in the evening he called me again and said it was entirely out. So that I went up to the works. I found that where the valve stem had entered the nut it was broken off short. Why it broke off I have not been able to reason out. But we replaced that particular one with Monel metal. That is a regular 36-in. hydraulic valve. I believe it is something that will be worth looking into later for valve stems in large valves.

MR. DIVEN. That is a little heavy to have breaking out, is it not?

MR. KILLAM. Yes; it is the first time I have caught it.

MR. LINCOLN VAN GILDER.† A couple of months ago I was informed by a gentleman in Philadelphia who represents a distributing firm, that there seemed to be a lack of uniformity in the metal, and that where you expected to get a non-corrosive article you got one that was quite readily attacked. I was wondering whether that had been permanently cured yet, and whether you can produce Monel metal that you can reasonably guarantee as anti-corrosive.

MR. ARNOLD. Yes, we do. I think perhaps the statements of failure are perhaps a trifle overdrawn. I am very sure from our own records that I can state positively that the percentage is a very small fraction of 1 per cent. And I think you will find the company will be very glad to make a replacement in case of unsatisfactory material of this sort.

MR. KILLAM. I would say that in figuring up the cost, as near as I could estimate, it was about 75 per cent. more for the Monel metal.

MR. ARNOLD. Did you have your own material machined out for you?

MR. KILLAM. Yes.

MR. ARNOLD. There is the difficulty that is being rapidly overcome, — cost of machining. A great many machine shops have complained of the difficulty of machining Monel metal, and they have charged exorbitant prices for machining. There is really no reason why there should be an extra charge at all, or, if any, only a very small one. It is merely the case of a little precaution in dressing your tools to get proper cutting quality.

MR. KILLAM. Wasn't that due particularly to the poor American tools made during the war?

MR. ARNOLD. A great deal of it. Then the fact that a great many machine shops took it as one of two things, — either as being like bronze, and giving it a bronze treatment, or being like steel, and giving it a steel treatment; and neither of them is entirely successful.

* Superintendent, Distribution Sections, Water Division, Metropolitan District Commission, Boston.
† Superintendent, Water Works, Atlantic City.

PROPER UNDERGROUND RECORDS.

BY R. F. JOHNSON.*

[*September 15, 1921.*]

Mr. Chairman and Gentlemen of the Convention, — I have no paper. I submit, however, an exhibit which I am going to leave on the clerk's desk for any of you to look at who may wish to do so, so that you may see how we keep our underground records.

In our city our water department was managed, up to about seven years ago, by a board of water commissioners, and seven years ago the form of government was changed so that the city is now managed by a commission. Our people believe in associations, and when they employed me as superintendent, quite a good many years ago, I was asked to take the position on the first of July, and the first thing they instructed me to do was to attend a meeting of the American Water Works Association in June, before I ever had anything to do with the water works. Since then I have absorbed a great deal from my attendance at the meetings of the American Association, and from the literature of this Association, to which I have been a subscriber for quite a good many years. And I thought it was no more than fair, after I had absorbed so much, to undertake to contribute a little, so that I asked one of our boys in the drafting room to make me a sample page of our underground records.

Previous to my being appointed superintendent, I was comptroller of the city, and previous to that time I had been in the accounting business, and I always believed that anything in that line should be left by the operator, or bookkeeper, or whoever it might be, at night, so that if he should never again appear that somebody else could take it up in the morning.

When I got into the water-works business I conceived the same idea. About the first thing I ran across when I took charge of these water works was to overhear the men say, "Well, John, didn't you, some years ago, put down a long connection along Brockway Street, and if you did, when we extended the main itself what became of that connection?" Another question would be, "How far is the main out from the curb on a certain street?" Another question would be as to the exact location of a valve. And I found that they were continually hunting up references at the expense of a great deal of time.

Then, when it came to the service connections, that was worse yet. I found reference books in the office saying that certain blocks had service

* Commissioner, Department of Light, Water, and Sewers, Saginaw, Mich.

connections of a certain size. If you wanted to know any more about any particular service connection you had to go back to the original permit.

So that this plan was gotten up, and on that page, which is a fair sample, it shows the exact location of the mains, the exact location of every hydrant, the exact location of every valve in feet and tenths of feet, and the exact location of every service connection, its age and size; and, in fact, everything about our system is in that book.

In talking with my fellow-superintendents in the neighborhood, a great many of them have objected to my system of records for the reason that perhaps it cost too much money, so that before I came away I looked up just what it did cost. We had wall maps on a scale of 440 ft. to the inch. Those wall maps, of course, would show which side of the street the main was on, and show which side of the street intersection the valve was on, but it was altogether too small a scale to show the details that we wanted. Matters of that kind we had to start with. Our city has 65 000 population, and that record is in 14 books, with 50 pages each, properly indexed. Each page is drawn on Paragon mounted drawing paper 18 in. by 24 in. upon a scale of 40 ft. to the inch, which gives plenty of space for all the notations required.

The property lines and reams of streets are shown in black and the mains and connections in red, and then the valves and hydrants in black. We cover 17 square miles of territory, we have 155 miles of mains, 1 342 hydrants, 1 362 valves in the mains, and 13 000 service connections.

Now, the entire record cost us to build $7 500, and it costs us to keep up, including the auxiliary valve books for the distribution force, and so on, about $1 200 per annum. It has cost $1 200 for the last few years for the reason that we have done a great deal more work than we ordinarily do. It would not cost us that much in normal years. So that I am going to leave these two papers here, and I should be pleased to have anybody who is interested in that line look them over.

I think that is all, Mr. President, that I care to say, except that there was a matter came up at the first meeting here, about charging for public use of water, and most of us — or, I think, all of us — were very much surprised to find that the Bridgeport Hydraulic Company do not get any revenue from the city of Bridgeport. We believe in our town we have that question solved, and solved right. In the first place, there is absolutely no question but what a charge for public use of water is the right principle. Right across the way from our water board office there is a very large foundry that pumps every drop of its water, — it does not pay us a cent for water, — and it is hardly fair for the water payers to pay for the fire protection on that plant.

In 1908 we had a citizens' water committee. By the way, Saginaw had been having citizens' water committees for a good many years, trying to get an improvement of the system. But that citizens' committee went into everything very thoroughly, — amongst other things the charge for this

public use of water, — and by agreement with the then board of water commissioners and the common council, and this water committee, and a citizens' mass meeting, we established the idea that the plant, although it is municipally owned, should be treated exactly as though it were a private corporation. In other words, the water department was told to take care of itself. We established a hydrant charge of $45 per hydrant, a charge of $250 per water trough, of which we had 40, and other charges for public use of water of all kinds, — the police department, fire department, parks, cemeteries, and flushing sewers, and so on, — until we got together a gross charge of about $80 000, or a little over. Then we credited to the city 1½ per cent. of the book value of plant in lieu of taxes, and we credited to the city a 4 per cent. interest as the city's equity in the plant, which meant that when it went into effect the plant was appraised at about $900 000, of which there was $450 000 of outstanding bonds. The other $450 000 we called " the city's equity," and we give them credit for 4 per cent. of that every year.

There is another charge that we make. In our city nobody handles any money except the city treasurer, and we charge him with the interest on the daily average balances that he gets from the bank, and that amounts to some $4 000 or $5 000 a year. We most always have about one hundred thousand dollars or more balance.

So that we get net between $40 000 and $50 000 a year for public use of water, and our people have been so educated that that public use of water goes into our budget just as much of a standard item as the maintenance of the police department. We think we have solved the question with one exception, and that is that the prices prevailing now are the same as prevailed in 1908, and we ought to get more.

Discussion.

Mr. J. M. Diven.* Do you allow any credit for the city treasurer's work in collecting water bills?

Mr. Johnson. No, sir.

Mr. Samuel H. Mackenzie.† I have been much interested in Mr. Johnson's talk, both in regard to his records and in the fact that the water department is maintaining itself, which I believe is the correct principle. We have been running on that principle at Southington since the plant was taken over by the town, about ten years ago, and it has worked satisfactorily. When a correct form of accounting such as that adopted by this Association has been adopted by a water department it will help to bring that practice about.

---

* Secretary American Water Works Association.
† Engineer Southington, Conn., Water Dept.

It might be of great benefit, especially to the smaller departments, if an exhibit could be arranged for some of our conventions, in which the blanks in use by the different departments for their meter records, service-box records, gate records, and pipe locations could be brought together and arranged so that we could look them over and perhaps get some ideas that would help us in our work. To bring the matter before the Association I will make the following motion:

The President is hereby empowered to appoint a committee to arrange for an exhibit of accounting forms and record blanks in use by the water departments and companies of this Association, provided the same receives the approval of the Executive Committee.

[Motion carried.]

THE CHLORINATION OF NEW ENGLAND WATER SUPPLIES

BY WILLIAM J. ORCHARD.*

[*Read September 14, 1921.*]

When the chairman of the Committee of the Water Works Manufacturers Association in charge of this evening's meeting asked for a title by which to designate this paper we are afraid that our sectionalism cropped out.

A New Englander by birth, training and education, whose first impressions while working with sample bottle or plumb-bob under the superior tutelage of Sedgwick, Goodnough and Foss have perhaps been colored by experiences following his emigration to other districts, may perhaps be pardoned for the local color of the data to be presented.

There isn't very much to say about " The Chlorination of New England Water Supplies," because relatively few New England water supplies are chlorinated.

Let us examine a few figures.

Nineteen hundred and ninety-six communities in the United States chlorinate water or sewage or both, with liquid chlorine. Only 128, or 6 per cent., of these are in New England. Twelve are treating sewage, leaving but one hundred and sixteen New England communities chlorinating drinking water. Nearly half, 43 per cent., of these are in Connecticut, where 51 communities use liquid chlorine to safeguard their water supplies; twenty-four are in Maine, eighteen are in New Hampshire, eleven in Rhode Island; Massachusetts has nine, while Vermont has three communities using liquid chlorine for their water supplies.

Scoring the states in this country in accordance with the number of communities using liquid chlorine, and starting with New York in first place with 254 and ending with Nevada in forty-eighth place with but one lone chlorinating community, we find Connecticut stands eleventh, Maine twenty-fifth, New Hampshire thirtieth, Rhode Island thirty-sixth, Massachusetts forty-first, and Vermont forty-seventh.

A manufacturer of chlorinating equipment naturally asks, Why this relatively small number of communities using liquid chlorine in certain sections of New England?

Now, in trying to answer that question, the speaker appreciates that he is skating on thin ice — dangerously near a deep hole labeled " The Johnsonian Controversy," and caution dictates that he skate the other way.

* Of Wallace & Tiernan Co., Inc.

But it is a fact that there is more resistance to the chlorination of drinking water in New England than in any other section of the country. Some of this is due to a firm, honest conviction in the purity and safety of unsterilized water supplies; some of this is due to complete deep-rooted faith in the absolute efficacy of storage and watershed patrol. But in the speaker's opinion the principal cause for this resistance to chlorination in New England is the marked aversion found in some quarters to the application of chemicals in any form to drinking water. It matters not if, as in the case of sterilization, a barrel full of chlorine will suffice for a Woolworth building filled with water, the objection is to the application of chemicals in any form — no matter what the chemicals may be. This attitude was clearly expressed by one of New England's most prominent engineers, who said to the speaker, " Up here, we don't want medicated waters."

We do not agree with the opponents of chemical treatment, but we have absolutely no doubt of their sincerity. We can only hope that they will believe that the rest of us are equally sincere as we try to persuade them to change their minds.

Boston, for instance,—or rather the metropolitan district,—is the only large community east of the Rockies that does not chlorinate its water supply as an added precaution.

But Boston points to its low typhoid records with justifiable pride — and takes the stand that perhaps other cities have to chlorinate their water supplies to obtain low typhoid rates, but Boston can get a low typhoid rate without chlorination, so " why put chemicals in the water?"

Of course, then comes the question of the potential danger of an untreated supply, especially where reservoirs are easy of access — but here again we approach the controversial, and turn the page — for such is not the purpose of this paper. But as though to compensate for some of its seeming neglect of the manufacturers of chlorine and chlorine control apparatus, New England has made many contributions to the development of the process of chlorination which the editors of the *News-Record* assure us in their current symposium has come to stay.

As time brings to light more facts concerning its nativity it seems more and more likely that the experimental work of Sedgwick and Phelps at the Massachusetts Institute of Technology in Boston,a score of years ago, was the corner-stone of our present practice in the chlorination of water supplies.

It was at Torrington, Connecticut, that Tiernan — then struggling with Wallace in the development of a practical ozone generator for the sterilization of water — worked with Phelps in checking a water-borne epidemic, made use of bleaching powder to sterilize the water supply and caused them to transfer their energies from ozonation to chlorination. It was at Stamford, Connecticut, that the first automatic chlorine control apparatus was developed, thanks to the patience and coöperation of the late and highly-esteemed manager of the Stamford Water Company, Mr.

E. L. Hatch, one of the earliest and always one of the stanchest supporters of chlorination.

The first recorded reduction in color obtained by treating water with chlorine was secured at Branford, Connecticut, by Minor, of the New Haven Water Company, where, under his patronage and with his keen interest, an entirely new type of equipment that holds great promise has been under test for nearly a year. It was at Exeter, New Hampshire, that Weston first introduced liquid chlorine to water before the coagulant in order to reduce alum requirements, a procedure that has now been adopted with success by many operators. And at the abattoir at Brighton, Massachusetts, liquid chlorine was first used to sterilize wash water used about the packing plant — a procedure that is now universal in the packing industry; while the Waterbury, Connecticut, Y. M. C. A. was one of the very first to use liquid chlorine to sterilize swimming-pool water.

So you see New England has a considerable responsibility for the position in which the process of chlorination now finds itself, and has contributed almost as much to this as it has to other developments in the field of sanitation.

There is much that New England still can do. We seem to be at a turn in the road where new standards of water are to be developed, or else new interpretations placed on existing standards. The symposium on chlorination in the current issues of the *News-Record* and Mr. Brush's article in the current issue of *Fire and Water Engineering* clearly points to some of the problems still to be solved. With the increased attention being given to the chemistry of colloids and to the electrolytic dissociation theory as exemplified by the interest in hydrogen-ion concentration, chlorination presents a wide field for study. And in that study the wholehearted assistance of all New England water-works men is needed.

In New England, more than in all the rest of the country, are located the men who since the late eighties have guided the development of water-treatment to its present stage. Their help is needed in the developments that are to come. That help will speed the day of arriving at a proper appreciation of the merits of various modes of water supply protection.

REINFORCED CONCRETE PIPE AS APPLIED TO WATER-SUPPLY LINES.

BY W. G. CHACE.*

[*Read September 1, 1921.*]

My association with the Lock Joint Pipe Company is comparatively recent, but my association with concrete for the carrying of water is not quite so recent.

People generally speak of concrete, or think of concrete, as the proper material for foundations, to be built in place within molds, for bridges or for dams, or for any structure which requires mass and compressive strength. They probably do not as often think about concrete of a quality which will prevent the seepage of water, especially through thin walls.

In order to make possible the carrying of water long distances it became necessary to get a moderately inexpensive material and a permanent material, and, as you will recall, the New York Board of Water Supply chose concrete for the great bulk of the length of the conduit. They used it largely limited to the lower heads, — practically to heads where the pressure was that of a flow line. For their siphons they used steel pipe, cast-iron pipe, lined or unlined, but generally lined with mortar.

In the Winnipeg water supply we had a similar proposition. The distance was 97 miles. The capacity desired was 100 million gals. per day. The location was through a virgin territory, and over a country which was practically prairie. The application of concrete for the entire project was, it seemed to me, and it seemed to those in charge, quite reasonable. Thus not only were the horseshoe sections, of which there were 75 miles, built of concrete, plain or with some reinforcement, but the pressure lines up to 90 ft. head were also built of concrete pipe reinforced, 10 miles of which were built in the trench, the other 12 miles being premolded pipe, for which the designs of the Lock Joint Pipe Company were chosen.

Now, the requirements for the pipe were such in that 97-mile stretch that it became necessary to obtain a mixture of concrete that would be water-tight. I won't keep you any longer than to say that from tests of 22 miles of the pressure pipes in the Winnipeg systems — which tests were made by displacement — along with tests to full working level of seven " cut-and-cover " sections, altogether 1 400 ft. (200-ft. sections at different places in the aqueduct), the nearest estimate we could get of the loss of water from the conduit itself throughout the whole 97 miles was one half

* Of the Lock Joint Pipe Company.

of one per cent. I think no similar project that I have heard of can show such a result, and we were fortunate in that because of the fact that we were able to get a material for our concrete which, with only a barrel and a quarter of cement per cu. yd., was tight enough, from specimens taken, so that it would stand 90-lb. pressure per sq. in.

It is possible, therefore, to make pipe of concrete sufficiently water-tight at the beginning; and one of the characteristics of concrete, as most of you may know, is that water-tightness increases in such construction with age and use, no matter whether the water carries the material in suspension or whether it be absolutely free of material in suspension. A concrete pipe line, therefore, should be given credit for its condition at the end of the first year rather than for its water-tightness at the time of laying.

So much for water-tightness.

Generally speaking, compressive strength is not the final desideratum, or the outweighing desideratum, in such concrete, but, rather, impermeability without any more sacrifice of compressive strength than necessary. We ordinarily make a practice of using a very rich mortar, or rich concrete; mortar for some classes of pipe and concrete for others. If our sand be harsh, or if we have difficulty otherwise in getting a water-tight body, we have introduced colloidal material into the mix for the purpose of cutting down permeation, and with great success.

Three weeks ago, in discussing this matter with Professor Abrams at Chicago, he told me of experiments they had made with colloidal material, in which he had investigated the effect of the addition of such material to concrete mixtures, observing the effect upon the compressive strength, and he found that, generally speaking, addition of colloidal material up to 10 per cent. of the weight of the cement caused a loss of practically nothing. In other words, an addition of colloidal material of 5 per cent. might reduce the compressive strength by 5 per cent.

So that the obtaining of an impervious concrete in such a manner is quite a practical and is quite a reasonable and well-worth method of getting the results aimed at. In regard to the use of concrete for the retaining of water under pressure, our practice has not been carried beyond a 100-ft. head with the thin wall that we use. Smaller pipes than 15 in. have not been attempted by this company, although in some other areas they are being made. But the limitation of cost,— because such pipe must be made on the location where the pipe is to be used,— the limitation of competition, the matter of gross earnings, and a few things like that, caused us to choose 15 in. as the minimum dimension for which the reinforced concrete pipe is offered. We still continue those limitations, the considerations governing them being almost continuously uniform.

Up to 100-ft. head reinforced concrete as such — that is, a wall of concrete having buried within it a mesh or cage or bar reinforcement — is satisfactory, and we have been successful in using a wall thickness as

low as 3 in., with concrete which has been poured into the molds in liquid form. This does not apply to articles of concrete which may be made with a dry mixture, but it must be a wet mixture of reinforced concrete. When it comes to higher heads than that, we have adopted the principle of establishing in the wall a cylindrical water stop, that water stop being a thin sheet of steel, as has been used with success by some other companies both on this continent and in Europe. On this continent the American Pipe and Construction Company some years ago, under Mr. Ledoux, who is here, and some other gentlemen who have done a great deal of work in that connection, completed a goodly number of lines which are of the same nature in a sense, although not made in quite the same method.

In Europe, pipe of that nature has been subjected to heads as high as 500 ft., and in diameters up to 48 in. and slightly larger. The 500-ft. head is not taken care of as to its bursting stress by the steel sheet itself, but the reinforcement to enable it to stand the bursting stress of that pressure is placed in the walls of the concrete, in the European practice, both within and without the steel sheet; but, in our practice, on the exterior shell of the pipe, i.e., in the exterior shell of concrete enclosing the steel cylinder.

Now as to the characteristics of concrete pipe for water supplies:

The minor characteristics, such as sufficient strength and rigidity, are available in walls 3 in. and upwards in thickness.

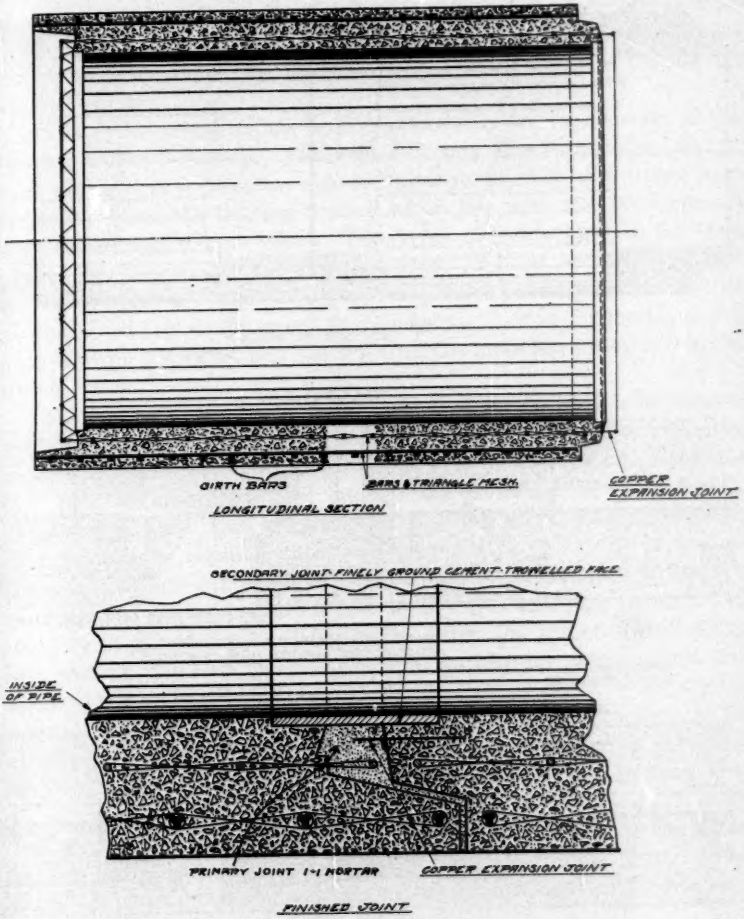
Water-tightness increases with age.

If the pipe be manufactured, as is ours, within steel forms which are kept sleek and clean, and true to dimensions, the interior and exterior of the pipe walls are smooth, and by virtue of the smoothness of the lining, pipe made of reinforced concrete has a very high carrying capacity, than which, I think you will find from the tests, there is no superior. The Department of the Interior at Washington, for instance, through their Mr. Scobey, issued not long ago a bulletin on the question of the carrying capacity of concrete pipe, to which reference may well be made. The results of the tests of one of the Lock Joint Pipe Company's lines is shown in that bulletin, and the coefficient of friction obtained. Our test on the Victoria line showed less than .011 as the value of n, which result could only be obtained by virtue of highly-polished, smooth interior forms.

The carrying capacity of concrete pipe obtains throughout its life. That is a very important feature in the carrying of pure soft water, particularly with soft water which contains no salts in solution. No tuberculation occurs. There is only one exception, and that is, if the water be from a lake there may be some algæ growth such as would be common to any pipe. But a party was telling me last week that the result of a test on concrete pipe in which there was an algæ growth seemed to show an increase in the carrying capacity. I could hardly understand that argument. My opinion would be to the contrary, — that the introduction of algæ

would slightly decrease the carrying capacity, but only to a small extent. It is easily cleaned.

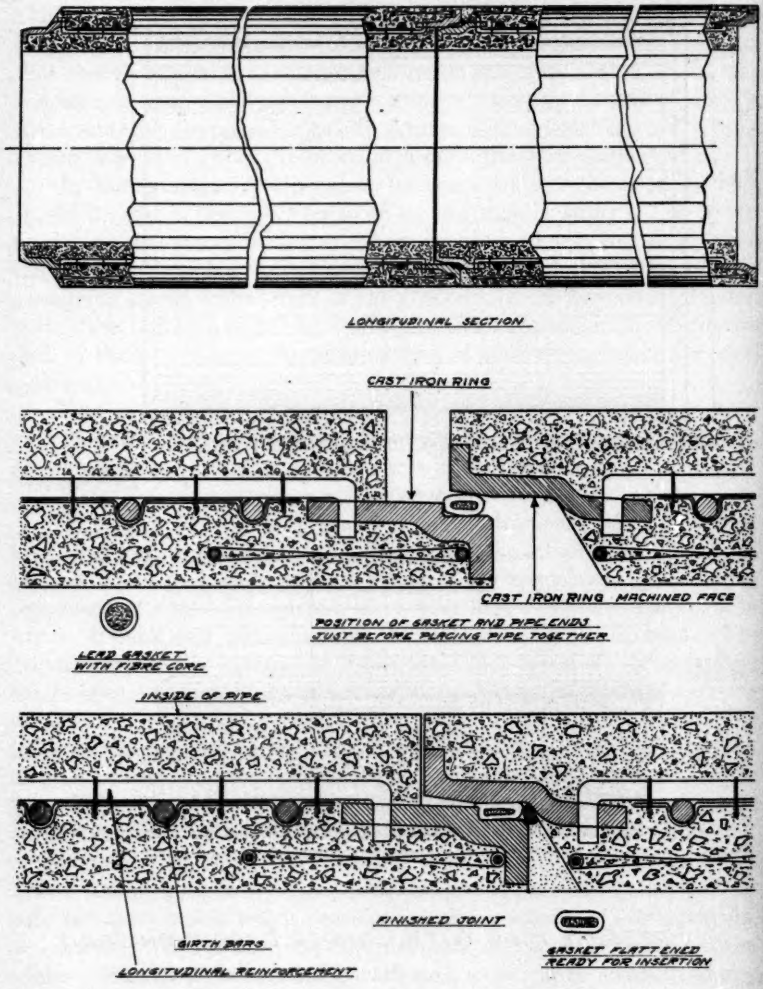
The reinforcement within the wall of a pipe is adjusted in a proper relation to the bursting pressure and to the earth load pressures, which



PRESSURE PIPE WITH COPPER EXPANSION JOINT

may apply to the location in which the pipe lies. We have made it a practice to modify that reinforcement by steps of, roughly, 20-ft. head, thereby gaining an excellent economy in the use of the steel. The reinforcement has in our practical work a low stress, — not over 12 000 lb. per sq. in.

That brings out immediately a very important fact in connection with reinforced concrete pipe for water supply, which is this: It is almost impossible in a well-built line to lose the ability to deliver the water to the terminus aimed at. A rise of pressure may split the concrete in such a


LONGITUDINAL SECTION
CAST IRON RING
CAST IRON RING MACHINED FACE
POSITION OF GASKET AND PIPE ENDS JUST BEFORE PLACING PIPE TOGETHER
LEAD GASKET WITH FIBRE CORE
INSIDE OF PIPE
FINISHED JOINT
GASKET FLATTENED READY FOR INSERTION
GIRTH BARS
LONGITUDINAL REINFORCEMENT

manner that water will seep through the wall along the crack caused by the rise in pressure, but parts of the concrete pipe wall will not be blown out. The pipe will remain a cylinder. Water may pass through the wall at the cracked section, where the heavy pressure may have hit the pipe,

but when that surge has passed, the reinforcement, by its elasticity, immediately closes the gap, and through the whole phenomena the water is delivered to the terminus aimed at. I have burst 66-in. pipe carrying two cylinders of bar reinforcement. It was designed for about 33-lb. pressure, and we had a pressure above 90 lb. when the concrete opened, and the water exuded the full length of the pipe section under test, but as soon as the pressure was released and the working pressure again admitted, there was no evidence along that fractured axis of losing water at the normal working pressure.

Now, your attention has been drawn chiefly to the question of the concrete in the pipe wall. The joint is a very important thing, and in most efforts to make concrete pipe for water supply lack of a proper joint design has been the limiting feature which has prevented some people from succeeding in that effort. Two types of joints have so far been utilized by this company. The first type, and the one which is still applied to pipes of diameters greater than 48 in., is the use of a copper ribbon buried half in the spigot of the pipe and half in the mortar of the joint between the spigot and the bell after the pipes have been laid in the trench.

For smaller pipes, in which the making of such a joint is unpleasant and difficult for the workmen, a slip joint has been devised consisting of a cast-iron spigot ring and a cast-iron bell ring, cast and molded right into each pipe section. Such pipe sections are ordinarily 12 ft. in length. These two cast-iron rings are secured together by longitudinal rods, which rods support the circumferential reinforcement in the shape of a cage. The spigot surface is finished in boring mills; the bell has cut within it a wedge-shaped groove in which is laid up an elastic lead-pipe gasket. The elasticity is provided by wicking made within the gasket. After filling with wicking, the lead pipe is rolled into an elliptical cross-section, and a hoop is laid up in the bell, after which the joint is made by forcing the spigot of the next pipe into that bell. The work is then complete, so far as the pipe laying is concerned, by that very process of forcing the spigot into the bell. That class of joint has proven under test to be a very efficient, water-tight joint, and one which is capable of taking care easily of all the changes in length due to the temperature variations in the water, and also of settlement, such as ordinarily takes place in the ground under backfill, or under certain foundations,—that is, not too perfect foundations, as one sometimes finds in trench work.

Discussion.

Mr. Allen Hazen.* We first used reinforced concrete pipes at Toronto, Canada, in 1909. The business was comparatively new then. On this work we had the materials of concrete on the ground, while iron pipe was somewhat more expensive than in the United States and the financial advantages of using concrete pipe were considerable. The pipe itself was very satisfactory. There was difficulty in getting the joints completely tight, and in fact they were never made entirely tight, but they were sufficiently tight to be reasonably satisfactory in the service where they were used. The heads were very small, — I think not more than 6 or 8 ft. in any case.

The pipe at Victoria, British Columbia, interested me very much. I had the pleasure of seeing it about the time it was finished. The joints at Victoria were similar, I believe, to the Toronto joints. It did not represent up-to-date practice. The interesting methods that Mr. Chace has described to us were not available at that time. The Victoria line was very far from being tight.

There was another interesting thing about this Victoria pipe. When it was laid, the interior was as smooth as glass, as Mr. Chace has told you. It was the smoothest pipe of any kind that I ever saw, and the quantity of water that passed through it was so high as to almost break the records for coefficients. Mr. Rust measured the water, and I cross-examined him very carefully as to his methods, to make sure that no error had been made, and I have no doubt of the substantial accuracy of the reported results. But the smooth surface did not last. After the pipe had been in use for a short time there was a great reduction in carrying capacity, and the coefficient came down to a very ordinary rating.

Mr. Rust wrote me that the smooth interior surface of the pipe had become quite rough. He thought this was caused by the free clay used in the cement, that was probably rather easily eroded by action of fresh water, even with slight velocity, and he thought that the removal of the clay probably loosened the particles of cement and hence honeycombed the pipe lining. In view of subsequent experience, the Victoria coefficient of discharge, obtained when the pipe was new and published as Mr. Chace has stated, is not a safe one to follow.

Mr. Theodore R. Kendall.† I would like to ask Mr. Chace how they make the curves in this line, other than the ordinary curves. Did you make them in the joints?

Mr. Chace. Generally speaking, the curves are made of small degree, or of large radius, by simply springing each pipe joint slightly. If they are of smaller radius they can be made with the copper joint by shortening the pipe on one side. This will alter the diagonal diameter

* Consulting Engineer, New York.
† Engineering Editor, *The American City*.

of the pipe. That brings together faces which are not absolutely alike, but the cross-sections are so nearly the same that they matched very well. On sharp angles we made the practice of building into monolithic joints. That takes care of the three conditions met with.

As regards the Victoria line, that line is probably exposed to the most severe conditions that any concrete line was ever asked to handle. It lies in an open trench in the side of the mountain. There is no backfill over any material portion of it, and it is subject to very great ranges of temperature every day. When it was built, it was built without any expansion joints or water stops at the joints.

The style of construction to which Mr. Hazen refers is the lock joint, such as we use in our sewer construction, where the bell reinforcement overlaps that projecting from the spigot end and the mortar joint seals both together. That class of construction had been utilized in water-supply lines only in the very earliest of our practice and for low heads. We offered to the city of Victoria at the time the use of a copper expansion joint, and recommended it, but it was a question of cost to them and was not accepted. Now, the line is not always running full of water. It is a flow-line conduit except where it crosses valleys, and only occasionally is it running full. A recent inspection by our president, and by engineers who have seen it, indicates that about 200 odd joints in that line are the ones through which nearly all of the loss of water is occurring in low temperatures. The quantity of water available is ample, the quantity delivered is ample, and the engineers in charge of it have expressed no concern, and have told us not to bother about it at all, as they would take care of these joints when necessary. It is a small matter to correct the situation by means of plastic material.

As to the roughness to which Mr. Hazen refers, I think that is a question of local experience solely. We have not run across it, to my knowledge, in any other water supply.

The information as to the coefficient of friction is from the report by Mr. Scobey, of the Department of the Interior. I do not think the test was made as soon as the line was completed.

MR. G. A. SAMPSON.* I would like to ask about the steel cylinder in the high-pressure pipe, — as to the thickness of it, how far it is imbedded in the second sheet of concrete, and as to whether it is combined with the reinforcement or not.

MR. CHACE. The steel cylinder is a new development. We believe thoroughly in the principle that no corporation or no idea can live unless it is growing, and we have been trying to enlarge our scope and improve our methods, and this is the latest step that has been taken in the expansion of the field of the application of reinforced concrete to water-supply lines.

The steel cylinder is designed as a water-stop primarily. The question came to us when we put it in, whether we should put all our reinforcement

* Of Weston & Sampson, Boston, Mass.

in that cylinder or only such of it as would make a cylinder practical to work with. A gage of 24 or 26 would be too light to handle and make a practical working unit of it. On the first job we used gages of 14 and 12. That was on a 36-in. line. I think our practice would be to not go to heavier gages than No. 14.

The cylinders are electrically welded together. A sheet is rolled into a cylinder, and then a longitudinal seam is run by an automatic electric welder. We are able to develop a very large proportion — it has tested as high as 100 per cent. — of the strength of the sheet.

The additional reinforcement over and above that is placed in the exterior shell. That reinforcement is not secured to the cylinder, but is secured within the outer wall upon longitudinal ties from bell to spigot end. We desire to keep this reinforcement distant from that cylinder so as to embed it thoroughly in the mortar of the exterior shell. The cylinder itself is secured to the cast-iron rings.

MR. J. W. LEDOUX.* The inside shell is probably quite as satisfactory to use as a reinforcement as to depend on the ordinary reinforcement, because the price of an iron in that shape (sheet) is usually about double what the price of reinforcement iron is. I think that must be the only reason why that can't be used as the complete reinforcement for the pipe.

MR. CHACE. No; there is another very practical reason in production, Mr. Ledoux, and that is this: Automatic electric welding can be done on a thin sheet at a higher speed than on a thick sheet; also, the additional steel placed in the exterior shell is by far the most economical and therefore that combination is the proper construction.

* Consulting Engineer, Philadelphia, Pa.

PIPE JOINT COMPOUNDS.

DISCUSSION.

[*September 14, 1921.*]

MR. MICHAEL F. COLLINS.* There are compounds before the water-works superintendents to-day called leadite, hydro-tite, and metallium. I would ask the superintendents who have used either for any number of years what their opinions are about it, and what results they have obtained. It is something, I think, that is worthy of consideration of everybody here to-day.

MR. J. M. DIVEN.† With the long record and a long experience with lead joints, which have proved very satisfactory, the speaker was slow to try any substitutes, nevertheless watched the development of leadite, the first one brought to his attention, and its use by others; with so many successes and the time test demonstrated, did finally try it. The first use was on a rather unimportant line, and where the pressure was low. The success with this induced further trials, and all were equally successful. The final test was the pouring of a joint for a 30-in. double tapping sleeve, two 8-in. outlets. This work was done in the spring, when the temperature of the water was rather low, and was made with the pipe line in use. The consumption, all passing through this line, was from 15 000 000 to 18 000 000 gal. per day, indicating a velocity of nearly 5 ft. per second, which would keep the pipe cool. The joint was successfully poured, the two taps made without starting any leak. The pipe line was under about 110 lb. pressure at the time.

A little more care is required in melting leadite than is the case with lead; however, little trouble was found in training men to its use.

MR. COLLINS. I should like to learn the life of these substitutes for lead. I know cases where a compound has worked very well; in my own case I have used some where I have had good results. But lead has been in use for hundreds of years, and whether substitutes are going to stand the test of time, or whether they will injure the spigot or bell end of the pipe, is something I should like to know.

MR. LINCOLN VAN GILDER.‡ I can't tell anything about how long it will go, but I know that it has gone nineteen years. Mr. Hawley left the company with which I am now connected in June of 1902, and he

---

* Superintendent, Water Works, Lawrence, Mass.
† Secretary, American Water Works Association.
‡ Superintendent, Water Works, Atlantic City, N. J.

poured the leadite joints previous to leaving Atlantic City. Those joints are in perfect condition to-day. We have used leadite almost exclusively for fifteen years, and it has always proven satisfactory.

MR. DIVEN. I think Mr. Hawley was about the first user in the country.

THE PRESIDENT. He was the first I knew of. The fact that men like Mr. Hawley and Mr. Van Gilder are keeping on with it speaks well for it

MR. GEORGE F. MERRILL.* Have you had any experience with leadite on steel pipe, or pipe of that kind?

MR. VAN GILDER. We have had a little experience with that. In connecting up large meters and putting in cast-iron pipe, it is our regular practice to take a wrought-iron pipe with one end threaded and insert a blank end in the bell of the pipe for the leadite, and that holds perfectly, just as in the cast-iron pipe.

MR. DIVEN. While on that subject, I might tell Mr. VAN GILDER a better trick. Take a threaded end and put a coupling on and insert the coupling in the bell end. You have more strength and less lead.

MAJOR LEONARD S. DOTEN.† About two weeks ago, in making connection between 6-in. iron and cement pipes I took a chance. Ordinarily, we have a lot of trouble in pouring the lead in there in making the cement keep the lead in place, but in this case it worked fine. We completed that particular piece of work and had the hole filled up inside of two hours.

MR. CARLETON E. DAVIS.‡ Has Mr. Van Gilder used the leadite up to 48 in.?

MR. VAN GILDER. No; we have not used leadite on larger than 24-in. I might say to the members that on our large lines we prefer lead.

MR. DAVIS. I have poured up to 60, but I don't know whether they are going to work or not. It is said frequently that leadite is more difficult to handle than lead in case of heavy vibration, like that near a railroad track.

MR. VAN GILDER. We have had no more trouble than with lead in those cases. The leadite is as easy to repair as the lead.

SECT. GIFFORD. Mr. Van Gilder, suppose you have a leak where the joint is improperly poured, or seepage around the entire joint, and it is a place where you can't draw off the water to clean the pipe; how is the repair made?

MR. VAN GILDER. I can explain that by taking a case of this kind, which we sometimes meet and accomplish in this way: You all know how difficult it is to cut off a section of old pipe and get it absolutely tight, and also the danger in pouring the joint with lead if there is any seepage. In this case we do not take the time to go and open our valves, but in making up the last joint we put the joint ring up, so that the leakage from any part

---

* Superintendent Water Works, Greenfield, Mass.

† Advisory Engineer on Sanitation, War Department, Washington, D. C.

‡ Chief Bureau of Water, Philadelphia, Pa.

of the pipe will pour from right under the plate ring, then we pour the leadite in from the top. Frequently it will pour solid, but if it becomes spongy at all there is too much water, and we take it out and pack it in either with lead wool or leadite to make the joint perfectly dry, but still the water is running.

MR. R. H. ELLIS.* Under what pressure would you be able to use leadite?

MR. VAN GILDER. Forty pounds normally. That is the highest I have tried.

MR. ELLIS. I have myself tried the experiment of calking up some small holes with lead wool. In my own case it did not work very satisfactorily, but it was under 140 lb. pressure.

MR. VAN GILDER. It is entirely safe for the workman to pour leadite molten right into water. It does not make steam of an explosive force. It pours at about 350°. You can pour it in the wettest joint you have got.

SECT. GIFFORD. There is one other question that I am interested in, and that is the experience of the members who use substitutes for lead in electrical thawing. I think I was told at one of our winter meetings that substitutes for lead were non-conductors of electricity. I was also told that there was 23 per cent. of iron filings in one of the compounds, and it ought to be a conductor. I have just finished laying about 8 000 ft. of pipe, mostly 12-in., and used leadite on most of it, but inserted a lead wedge in every joint. I am not afraid of electrolysis — I don't have any — but do want to thaw by electricity if it becomes necessary. I should like to know if it is possible to thaw without the lead wedge, or some similar substance to carry the electricity.

MR. SAMUEL E. KILLAM.† In addition to wooden joints, there are two joints in the Metropolitan Water system where we use a substitute for lead. These wooden joints leaked in winter on account of the contraction of the pipe line, and we tried hydro-tite. The first few days they leaked considerably, and I had my doubts whether it would ever take up, but in two months they were entirely tight. The wooden rings were left in between the bell and spigot. In testing these joints for resistance to electric current after the hydro-tite was poured, it was observed that there was considerable resistance in the material.

PRESIDENT SHERMAN. In your case, as I understand it, you had a wooden ring between the bell and spigot, so that there was no contact between the bell and spigot?

MR. KILLAM. Yes, the wood ring was left in place and hydro-tite substituted for wood staves for remainder of joints.

MR. MERRILL. I wonder if any one has any information on leadite joints that have been laid for several years. I have been informed that after a year or two the conductivity increases quite considerably, — that

* Superintendent, Board of Public Works, North Andover, Mass.
† Superintendent Metropolitan Water Works.

as the rusting takes place it makes a good deal better conductor. I think that age has something to do with those joints.

THE PRESIDENT. Mr. Killam, were your joints very nearly new when you tested them for your electrical resistance?

MR. KILLAM. Yes.

MR. VAN GILDER. Leadite was poured in 1914 on a 20-in. line, about 10 000 ft. long. That would give age enough, I presume, to properly answer the question. We could test that quite easily.

MR. PATRICK GEAR.* The only experience I have had with leadite is this: My predecessor bought 100 lb. of it in 1910 and we experimented a little with it, but couldn't pour it just right. The man selling told us the great advantages of the stuff, and I asked him if he could pour a joint that would be watertight in twenty-four hours. "Sure!" he said. We had him pour two or three joints, and I let the water on when he told me to do so. It sprayed all around. I left it there for twenty-four hours, and it was still spraying. It stayed there for a week and it was still spraying. I said I couldn't afford to use that stuff and then wait for a week to see whether it is good or not, because when I use lead I cover it up before testing it at all.

Another young man came along, selling leadite, and telling me the great merits of it. I asked him if he could pour a joint and make it come out successfully, and he said that he surely could. I let him pour three or four joints. We let the water on after a short time and it burst out all around the room. He left in the course of three or four days, and I haven't seen him since.

They have not poured a joint successfully yet, so that I have not bought any more.

SECT. GIFFORD. I will send you up one of our laborers.

MR. GEAR. He will be a failure like the rest of them, I am afraid.

Another gentleman came along a year ago who had a substitute for lead which he called by another name. He poured four or five joints and they were fairly good, but there was nothing that would give me faith enough in it to make me pour a joint under a railroad track and cover it up.

MR. DIVEN. What pressure did you put on in your test?

MR. GEAR. City pressure; 85 to 100 lb.

* Superintendent, Water Works, Holyoke, Mass.

STEAM BOILERS.

BY F. W. DEAN.*

INTRODUCTION.

At the present time, more than ever before, it is of the greatest importance to carefully consider the most economical type of boiler and engine. In all parts of the world, even in coal-producing countries, the price of fuel as well as of all other requirements is abnormally high, and the types of boiler and engine that will give the most efficient performances without objectionable features should be sought and used. Greater care should be taken in firing boilers, as by care much coal can be saved, but I find increasing indifference to this by firemen.

It seems to me that there are more notions and superstitions abroad concerning boilers than about any other common thing.

The general design of a boiler is of less importance than is commonly supposed. If a boiler has sufficient heating surfaces so arranged that the hot gases circulate through or about them, if they divide the gases into thin streams, if the admission of air for combustion is at the right place, if the leakage of air into the gases where it does no good and cools the boiler is substantially prevented, if the surfaces can be cleaned and the fire box and grate are such that the combustion is good, the boiler will do well. Evidently these requirements admit of an infinite number of arrangements of parts. A "good steaming" boiler is almost any kind of boiler that is amply large for the work to be done. As generally used, the expression "good steaming" is meaningless.

The idea is commonly held that there is special virtue in radiant heat. The absorption of such heat merely extracts it from the hot medium, and if it were not at that time removed it would be available for absorption elsewhere by direct contact with the boiler-heating surface, and with equal value. If a fire box had no surface which could absorb radiant heat and a proper amount of surface which could absorb it by contact, the effect would be the same. The surface which has the opportunity to absorb radiant heat is usually that which deals with the hottest gases and for this reason is more active in absorption than any other surface. For these reasons it should not be supposed, as it commonly seems to be, that radiant heat is something that would be lost if there were not surfaces present to absorb it.

---

*Of Wheelock, Dean & Rogue, Boston, Mass.

Definition.

A boiler consists of two fundamental parts, a furnace for burning fuel and producing heat and a part containing water and absorbing heat. The furnace can be arranged for burning coal by hand firing, or by mechanical stokers. In either case, the coal should be burnt as perfectly as possible in order to economize, and it is possible with either to admit too little or too much air. Combustion is a chemical process, and should so occur that the product of combustion will be carbonic acid, and the quantity of this gas can be ascertained by an inexpensive and easily used piece of apparatus. The presence of a boiler with a furnace is not necessary for the proper combustion of coal. The function of the boiler is to absorb the heat after it is generated, and it should not be so formed or placed that it will, to any material extent, or at all, interfere with the chemical process of combustion. From this it is evident that there may be many different ways in which the surfaces of a boiler may be arranged. It depends somewhat upon the coal whether a large space is needed for good combustion, but it can be said that for coal with a small quantity of volatile matter, not much space is required. For example, a locomotive or a Scotch marine boiler will give most excellent results, although there is not much space for combustion, and the water-containing parts of the boiler are near the fire. These results plainly show that the idea that large space is needed for combustion, except with pulverized coal, and oil, which are moving fuels, is a mistake. If the air is admitted in the right quantity at the right place, good combustion will result, even if a relatively cold boiler shell is in close proximity.

In the case of bricked-up boilers, large fire chambers result in opportunities for air leakage, and such air seldom, if ever, enters where it aids combustion. What it in fact does, is to cool off the boiler and make a demand on the chimney which results in a waste of its capacity, and, if economizers are used, to diminish their effect.

Internally and Externally Fired Boilers.

In one respect boilers are divided into two general classes, known as internally and externally fired. The locomotive type, vertical fire tube, and Scotch boilers are called internally fired because the fire box and grate are within the boiler. The common American horizontal return tubular boiler and many others having the fire box below the boiler, or in front of it and not structurally a part of it, are called externally fired. Internally fired boilers have the advantage of having little or no brickwork, the latter being always a source of trouble. They do not permit air to leak in and cool the gases of combustion, and thus reduce economy and make great demands upon chimney capacity. A considerably larger quantity of air than is usually permitted to enter a boiler fire box is often desirable, but it should enter only where it aids combustion.

Fire-tube and Water-tube Boilers.

Besides internally and externally fired boilers, there is another division of types, known as fire-tube and water-tube boilers. In fire-tube boilers the fire passes through the tubes and the water surrounds them, but in water-tube boilers the fire passes around and between the tubes, and the water is inside of them.

The water-tube boiler was devised for the purpose of preventing explosions at a time when the shells of fire-tube boilers frequently exploded. It was an attractive idea to have the water confined in small tubes which probably would not explode, and which, if they did, would do relatively small damage. Unfortunately, water-tubes boilers consist of headers and drums as well as tubes, and of them there have been some very serious explosions, and tube explosions are common occurrences. Explosions of fire-tube boilers are now virtually things of the past, and were almost entirely caused by the use of lap longitudinal joints. The tubes of such boilers never do anything worse than leak. In most of the states of the United States lap joints are prohibited by law.

There is a great variety of water-tube boilers. Some consist of headers made in various ways, one at each end, connected by tubes. The headers are connected to one or more drums above. The tubes are always inclined, sometimes highest at the front end and sometimes at the other. The headers are frequently inclined so that the tubes are at right angles to them. Occasionally the headers are vertical and the inclined tubes enter small inclined surfaces pressed in the headers.

Sometimes the drum runs from the front to the back header, and sometimes it is placed above the lower header and parallel to it. The latter are known as "cross-drum boilers," and in my opinion are superior to the other, because the drums receive the steam uniformly from one end to the other, in small amounts per unit of length, and the feed water is supplied more evenly to the lower header. They carry the water better than the longitudinal drum boiler, show a truer water level, and are more likely to produce dry steam.

The headers of the water-tube boilers described are sometimes made of steel plates, two for each header, connected together in some manner at the edges. One of the plates is called the "tube plate" and the other the "hand-hole plate." The tubes are expanded into the holes of the tube plates and project through the plate about half an inch, this projection being bell-shaped.

The plates of the plate headers are usually stayed together by screwed staybolts headed over. The stays should have small holes drilled from each end to a depth of at least one-half inch beyond the inner edge of the plate, so that, if they break, steam and water will escape and cause the rupture to be known. These holes are often $\frac{3}{4}$ in. in diameter entirely through the staybolt, and those that are not utilized for tube blowing are plugged with metal plugs, of which there are a number of kinds.

It is necessary to close the holes in the hand-hole plate, and this is done in various ways. Each hand hole is usually just large enough to allow one tube to pass through, but sometimes, if the tubes are small, it is large enough for four.

Other boilers have the headers formed of vertical rectangular boxes, each wide enough for one vertical row of tubes, closed at the lower ends and placed side by side, touching each other. The tops of this kind of header are connected to the drums by means of short pieces of pipe called "nipples", which are expanded in holes in the top of the header and the bottom of the drum. Plate headers are usually flanged and riveted to longitudinal drums, but to cross-drums they should be connected by means of expanded nipples. Boilers with narrow header boxes are likely to allow air to leak in between them, and the spaces between them must be calked with a suitable material; but, nevertheless, they are likely to leak.

Workmanship.

Good workmanship on boilers is frequently mentioned but it is not so well understood. It consists in having the rivet holes drilled and exactly matched in the adjoining plates, rivets filling the holes, and plates in contact, or so near it that a steel feeler 0.003 in. thick cannot touch the rivet when slid in between the plates before they are calked. If staybolts are used, the threads should fit tightly and the heads be well formed. Tube holes should not be too large, so that it will not be necessary to expand the tubes too much. The difference in diameter of holes and tubes should not exceed $^1/_{32}$ in. Tubes should be neatly beaded and should not crack by beading. Care should be taken to curve the plates and butt straps accurately to the edges. The heads of rivets should be central with the rivet shank, with a maximum error of $\frac{1}{8}$ in. There are many things to be considered in addition, but it is hardly worth while to mention them here.

Baffles.

The baffles of water-tube boilers are means of dividing the spaces among the tubes into passages for the circulation of the hot gases, in order that the tubes may be well swept by the gases and have an opportunity to absorb the heat which they contain. The baffles are sometimes at right angles, or nearly so, to the tubes, and sometimes parallel to them. I prefer the latter method because the baffles are then simpler and more durable than the others, are more likely to be gas tight, and can be more easily applied and renewed. Besides this, the gases more completely sweep the tube surfaces, and by the use of hollow staybolts in connection with them, soot blowers are more easily applied and permit blowing parallel to the tubes, which is more effective than blowing at right angles to them, this being necessary when vertical baffles are used. Boilers with transverse

baffles cause the gas from the fuel to move in parallel vertical streams, and those streams having an excess of air have little chance of meeting those with combustible gases, and burning them, as is the case with boilers having horizontal baffles.

Experiment shows that horizontal baffles can be made of steel plates, except on the lower row of tubes. The plates will usually touch the tubes on top and bottom, the tubes thus conducting heat from the baffles and promoting their durability. The advantages of steel plate baffles are that they have fewer openings between them than tiles to leak gas, do not crack and get out of place, are thinner, and thus enable a boiler of given dimensions to have more tubes than when tile baffles are used.

In designing horizontal baffles the tendency is to make them too short in order to provide sufficient area of gas passage between their ends and the headers. Measurements of the drafts and velocities in the passes and between the baffles show that the gases pass very close to the ends of the baffles, so that most of the space between the ends and the headers is useless. The same thing is shown by baffles placed in a wide, shallow stream of water. By placing oil upon the water it will be plainly seen that the water passes close to the ends of the baffles and the water in the remaining space is stagnant.

In horizontal baffling the lowest baffle should always be on the bottom row of tubes, for otherwise there will be tube surface under the baffle which is inactive and useless. Similarly, the highest baffle should be on top of the highest row of tubes instead of under them, in order to render these tubes efficient. The lowest baffle should always be in contact with the front header, for, if not, any air that enters the fire door of hand-fired boilers passes up in contact with that header, cools the boiler, and does not support combustion. This is true to some extent when stokers are used, for the hopper may not be full of coal, thus giving air passage, and when it is, the air passes through the interstices of the coal above the combustion level. Boilers with vertical baffles always have this defect, and this is another reason for preferring horizontal baffles.

By making the baffles longer, the gases are compelled to sweep over more of the tube surface, and this increases the economy and adds somewhat to the forcing capacity of the boiler. By the latter it is meant that the economy is well maintained when the fuel consumption is increased well beyond the intended rate, or, in other words, the efficiency curve is straighter than in the case of a boiler with short baffles.

Still further, the economy and forcing capacity are improved by increasing the number of baffles, and thus the number of passes, and the number should be made as great as is consistent with a practicable loss in draft, for the greater the number of passes the greater is this loss. Many boilers with horizontal baffles have only one at the bottom and one at the top, but such boilers would be more efficient if more baffles were used. If

it were possible it would be best to have a baffle on every layer of tubes, but the draft absorption would be too great and cleaning impossible.

In the case of a water-tube boiler with headers and straight tubes, as before stated, baffles at right angles to the tubes are frequently used, and of course the gases move nearly at right angles to the tubes. The greater the number of passes, the greater is the ecomomy and the greater the capacity of the boiler to stand forcing beyond its rated power without greatly diminished economy, as in the case of boilers having baffles parallel to the tubes. Many boilers with transverse baffles have large spaces between the tubes and baffles and thus allow gas leakage and loss of economy.

In both kinds of water-tube boiler the gases make every effort to short circuit, or, in other words, to avoid passing into corners or parts of the boiler where there is the least obstacle. This is not only proved by draft and temperature measurements, but can plainly be seen by providing inspection holes in the sides of the boilers. Where there is no flame, sparks show the paths of the gases.

Water-tube Boilers with Bent Tubes.

Besides the water-tube boilers already noticed, which have straight tubes, there are those with drums and bent tubes, and no headers. These boilers are made in various ways, the simplest having two drums, one above the other, and parallel to the front, connected together by the tubes.

Another form has one drum at the bottom and three at the top, parallel to the front, the latter being connected with the bottom drum by bent tubes, and the upper drums connected together by such tubes. Another has one drum at the bottom and two at the top. Still another has two drums at the bottom and five at the top. In fact all tastes can be satisfied.

Still another well-known form is that having two drums at the bottom and one at the top, all at right angles to the front. The tubes run from both bottom drums to the top drum and the grate is between the two lower drums. This boiler is used chiefly in marine service.

Boilers of the above types have no hand-hole plates.

Methods of Closing Holes in Hand-hole Plates of Water-tube Boilers.

In the header type of water-tube boiler the hand holes can be closed by means of plates and gaskets secured by means of yokes and bolts. Each plate may cover one tube, or as many as four tubes if the latter are sufficiently small. It is customary for one plate to cover one 3-in., 4-in., or 5-in. tube, or four 2-in. tubes. A more modern, and, in the opinion of the writer, a better method, is to close each hole with a pressed steel tapered plug or cap, inserted from the inside. This requires no gasket, and is easily inserted, removed and re-inserted. It seldom leaks, and if it does it can be pulled in a little more and made tight.

Circulation in Water-tube Boilers.

Much has been written about circulation in water-tube boilers, but it is sufficient with few exceptions. It is important in such cases that the water should be freely supplied to the tubes and that sharp angles should be avoided unless the water is supplied from a large volume in which the velocity is low. It is, in fact, an important principle, that, of all parts of a water-tube boiler, the tubes themselves should have the least area for water passage, so that the entrance to the tubes and their exit should be unimpeded.

In the header type of straight-tube water-tube boiler, the most active circulation is through the lowest row of tubes and moves from the lower to the higher header. The circulation diminishes in this direction in the tubes above until near the middle row it is slight and may be in either direction. Above these the circulation is in the opposite direction to that in the lower tubes. This has been clearly shown by propellers in the tubes, the shafts of which pass out through stuffing boxes in the hand-hole caps opposite the tubes, the rotations being registered by an electrical device. The above refers particularly to cross-drum boilers, but in boilers with longitudinal drums the water in all of the tubes may sometimes move in one direction, and the return may be through the drum.

The boiler in which these circulation measurements were made was one having inclined headers, and the front header lower than the rear. The drum was parallel to and above the front header, to which it was connected by means of a pressed steel collar, in the limits of which were holes in the bottom of the drum for connecting the water space of the header with that of the drum. The feed water was distributed longitudinally in the drum and descended into the header. The top of the rear header was connected with the drum by means of tubes, and these served to carry the steam made into the drum.

Circulation nearly always takes care of itself, and while some boilers appear to be designed to prevent circulation, it takes place, nevertheless.

Steel Casings.

Water-tube boilers are frequently enclosed in steel casings, and always in marine work. This is a good thing and keeps the brickwork in good condition on the outside, and was originally done in land practice to prevent air leaks through the brickwork. It does not succeed in accomplishing this as it is found by piercing the casing and brickwork with observation holes, that jets of air can be seen burning in the boiler gases as they enter from the brickwork in various places. The air finds its way under and behind the brickwork from the ash pit, and enters the fire at numerous points.

Drum Heads.

A great number of heads of the drums of water-tube boilers have blown out and caused disastrous explosions. This is usually, and perhaps always, caused by cracking and erosion at the flange angle of the heads, which is probably reduced by the breathing of the heads with variations of pressure. If the material is somewhat cracked by the breathing action, the corrosion will be accelerated. Otherwise there is no more reason for corrosion at this point than elsewhere. In consideration of this defect of drum heads I have for some years advocated staying-drum heads, made in the customary manner, by means of gusset stays, as if they were flat plates. I consider drum heads with the convex surfaces inward safer than when outward. According to the Code of the American Society of Mechanical Engineers, such heads can be used if they are made of sufficient thickness.

Steam Pressure.

There is no difficulty in making water-tube boilers to carry any ordinary pressure up to say 300 lb. or 400 lb. per square inch or even more. Tubes with pressure inside of them will, of course, stand any pressure desired without being thick, and, in fact, they will not be of much thickness even if used to carry higher pressures than have been used. This is particularly true if the tubes are small, — say, 3 in. or less in diameter. A trouble, however, comes from the failure of tubes, from dirt, and this occurs in all water-tube boilers.

There is no ordinary limit to the holding power of tubes when expanded into headers or drums, especially as they always project through headers or drums about $\frac{1}{2}$ in. and are made bell-shaped.

In regard to drums, if they are pierced by as few tubes as possible and the longitudinal joints kept away from the tube holes, the drum can be made sufficiently strong to stand any probable pressure. As for the drum heads, there is no ordinary limit in pressure. While for large boilers, drums are frequently made 60 in. in diameter, it is my opinion that no boiler, however large, requires a drum of more than 48 in. in diameter, and seldom as large, especially if the boiler is of the cross-drum type, unless a large drum is necessary to accommodate tubes.

Sizes of Tubes of Water-tube Boilers.

In water-tube boilers for land service, the diameter of tubes range from 2 in. to 4 in. In my opinion, they should not in general be larger than 3 in., for I fail to see anything gained. By the use of 4-in. tubes the boiler is larger for a given capacity than with smaller tubes, and the gases are not so effectively subdivided. The length of tubes has a bearing on the diameter, and the limit of length for a 3-in. straight tube may be said to be about 20 ft. I think that the experience of many engineers during the late

war with marine water-tube boilers will affect their opinion, and that boilers of the marine type with comparatively short tubes of 2 in. to 3 in. in diameter will be more commonly used for land purposes than heretofore.

I fail to see any reason for having the tubes more than one inch apart, for this distance gives excellent service with all kinds of coal, or with oil fuel.

Method of Taking Steam from Boilers.

Experiment shows that the best method of taking steam from boilers is through the perforations of a pipe with closed ends, along the top of the drum and shell. The pipe should be as close to the top as possible and perforated along the top with holes not exceeding $\frac{5}{8}$ in. in diameter, uniformly distributed from end to end. The aggregate area of these holes should be such that the velocity of the steam shall be fully 8 000 to 10 000 ft. per minute. When this arrangement is carried out the pipe acts as a steam separator, as has been amply proved by tests. The steam nozzle should be in the center of the drum, so that the steam shall be drawn equally from all parts. The safety valve should never receive steam through the perforated pipe.

Boring the Insides of Tubes of Water-tube Boilers.

There are several kinds of tube borers that are specially made for boring out the insides of tubes and clearing them of scale, and such apparatus should be furnished with the boilers. For boilers having bent tubes expanded into drums, borers are so made that the operators are not required to enter the drums.

Fire-tube Boilers.

Although much of this paper has been devoted to water-tube boilers, it should not be inferred that fire-tube boilers are not meritorious. On the contrary, they are in most respects equal or superior to water-tube boilers. As high pressure as is usually desired can be carried on them, and when built according to modern requirements are safer than water-tube boilers, as can be readily shown by the records of explosions. The chief factor in making them safe, as before implied, is the use of butt longitudinal joints.

The American Under-fired Horizontal Return Tubular Boiler.

In the United States the most commonly used boiler is the horizontal return tubular boiler set in brickwork. The fire is under the boiler, the products of combustion pass to the back end and then come forward through the tubes. Common sizes are from 24 in. to 90 in. in diameter, and in some of the latter the heating surface amounts to more than 4 000

sq. ft. Boilers of this size are rated at 400 h.p. and some are worked up to 1 200 or 1 300 h.p., and have been for eighteen years or more.

Boilers of this type have been built up to 120 in. in diameter, and in my opinion are practicable and safe even for 200-lb. pressure or more. The plates would be thick, but the heat-conducting power of thick plates is almost as good as that of plates of the thickness commonly used, and the water has unlimited capacity to absorb the heat.

Dirt on the fire side of plates prevents heat from entering them, the plates themselves present almost no resistance to the flow of heat, and dirt on the water side of the plates prevents the heat from leaving them, and is the sole cause of overheating. Such dirt has the same effect on thin plates as on thick, and sometimes causes bulges. Bulging, however, does not cause explosions, and it can be prevented from increasing by keeping the boilers clean. It is best to allow dirt to accumulate on the outside of the bottom plates, as it is a slight protection, and its loss as efficient heating surface is slight.

Referring still further to thick plates, in 1890 an important paper was read before the North East Coast Institution of Engineers and Shipbuilders in England, by W. Kilvington and Alexander Taylor, on the use of thick plates for the furnaces of marine boilers. It had been for many years considered that $\frac{3}{8}$ in. was the greatest advisable thickness for such furnaces. This after a few years was increased to $\frac{1}{2}$ in., and in 1890 few engineers objected to furnaces $\frac{5}{8}$ in. thick. In 1890 there had been furnaces at sea for three or four years $\frac{3}{4}$ in. thick and subjected to 160-lb. pressure without failure. About the same change of opinion on this subject has taken place in regard to the thickness of plates of horizontal return tubular boilers.

The writers of the paper referred to stated that they knew of no furnace that had collapsed from being too thick. Cases of collapse have always been due to oil and dirt which accumulated on the furnaces, and this is the only cause of the bagging of horizontal return tubular boilers. It is also the usual cause of the bagging and explosions of the tubes of water-tube boilers.

The authors investigated the relative heat resistances of $\frac{3}{4}$ in. and $\frac{5}{8}$ in. plates and found that of the former only 1 per cent. greater than the latter. They show that this was long ago known by Rankine, who wrote: "The external thermal resistance of the metal plates of boiler flues and tubes, and other apparatus used for heating and cooling fluids, is so much greater than the internal thermal resistance, that the latter is inappreciable in comparison; and consequently the nature and thickness of those plates has no appreciable effect on the rate of conduction through them." Rankine also states that the results of evaporative tests of boilers justify the disregard of the effect of thickness on the rate of transfer of heat.

Kilvington and Taylor concluded that they would not hesitate to make furnace plates 1 in. thick, and that the same amount of scale would cause a thin plate to collapse as soon as a thick plate.

In 1867 Chief Engineer Isherwood, U.S.N., made some experiments on the transmission of heat through plates varying from $\frac{1}{8}$ in. to $\frac{3}{8}$ in. in thickness, a variation of 300 per cent., one side being exposed to steam and the other side to water, and the difference in the rate of heat transfer was not measurable.

All of the above reasoning applies to horizontal return tubular boilers, and the only inference to be drawn from it is that safety and efficiency are not affected by the thickness of the plates. Since 1880 thicknesses have increased from $\frac{3}{8}$ in. to $\frac{3}{4}$ in., and the writer has put in 90-in. boilers with plates having a thickness of $\frac{1}{32}$ in. more than $\frac{3}{4}$ in., and several 84-in. boilers with $\frac{3}{4}$-in. plates, which act in no respect different from boilers with thin plates. Some of these boilers have been in use nearly twenty years. All of these considerations show that there is no reason for anxiety in the presence of a well-designed boiler of the type under consideration if it has been built of good material.

The plates at the circular joints should be planed so that the double thickness at this point will not be excessive. This does not reduce the strength of the boiler, as the stress in a circular section of cylindrical boiler is very small and the two thicknesses at this point are greater than the thickness of the unreduced plate, so that longitudinal rupture at this point cannot occur.

Nor need there be any fear that the plate above the fire suffers in quality, for many boilers have been subjected to severe use for many years without apparent effect on the plates above the fires, and in one case, from a condemned boiler of the H. R. T. type, which had been in use many years, test pieces were cut from the plate which was above the fire, and the tests gave the same results as when the plates were new.

Riveted Joints.

It has been established, as I have before stated, that the cause of explosions of horizontal return tubular boilers has been the existence of lap longitudinal joints. This was due to the departure of the shell at the joint from the circular form and the consequent many bendings of the plate in the effort to become circular when pressure was applied. With the application and removal of pressure and the consequent bending back and forth of the plates, they finally cracked. If they are maltreated in bending, as plates in the past have been, they will crack all the sooner.

This was overcome by butting the plates and placing a covering plate on each side. Since this was done only one explosion of a horizontal return tubular boiler with such joints has occurred, I believe, and that was not in the joint. It was at a badly corroded place which was thereby weakened.

The prevailing butt joint used in this country for shells and drums of boilers is defective and likely some time to cause explosions. The

reason for this is that the inside butt strap is wider than the outside, and the joint is a combination of the lap and butt, and is, therefore, defective. It is defective because it is a non-central resisting device and still bends the plate and may therefore cause cracking. It is not, for this reason, the best joint, and, considering the prime importance of safety, should be abandoned. The covering plates, or butt straps, should be of equal widths, with all rivets in double shear, and until they are so made, as they are in most marine boilers, some danger will exist. Several of these one-sided joints have cracked, but fortunately leakage showed the danger before an explosion occurred.

The circumferential joints of horizontal return tubular boilers are troublesome, and there is no need of their existence since there are rolls of sufficient length to roll up plates long enough for boilers having tubes 20 ft. in length. The Massachusetts rule limiting the length of longitudinal joints should be repealed, and permission should be given to use plates of any length to persons desiring to avoid circular joints.

Making the Most of Horizontal Return Tubular Boilers.

With the exception of several designs made by the writer, boilers of this type are not provided with as many tubes as possible and desirable. The boiler users' interests are thereby not sufficiently considered and unnecessary room is taken up by the boiler plant. The boiler makers seem to have some fear of providing the boilers with as many tubes as they can stand without disadvantage in any respect. Whether they think they will prime or in some way misbehave I do not know, but if perforated steam pipes (or dry pipes, as they are often called) are used and the steam nozzles are placed about midway between the ends, the boilers cannot be made to prime no matter how hard they are worked. I favor placing the tubes nearer together and higher in the shell than usual. I have designed many such boilers with no regrets. The effect of this in 90-in. boilers with 3-in. tubes 20 ft. long is to increase the heating surface and horse power 33 per cent., which is something that should not be ignored. The makers of this type of boiler are not sufficiently aggressive.

Method of Supporting Horizontal Return Tubular Boilers.

It is common to support this type of boiler by means of four or more brackets resting upon brickwork, or by suspending it at four points from two overhead steel beams resting upon columns. When this is done it is impossible to adjust the loads so that they will be equal at each point, and in fact three of them, sooner or later, will support the whole load, especially if the foundation settles. This shows the folly and danger of using anything but the three-point suspension, provision for which should be made in the first place. When the boiler itself determines the three points, one

support will be overstrained. A three-legged stool rests firmly upon any irregular surface, and is just as stable if one or more points settle.

The three-point suspension was originated by the late Orosco C. Woolson, of New York, and for this he has not been sufficiently honored. When the three-point suspension has been carried out, connection has been made to four points on the shell, but the two rear points have been connected to an equalizing beam above, which has been hinged to the beam resting upon the supporting columns. A simpler, better and cheaper method is to have the rear end supported by a bracket riveted to the rear head of the boiler, as thereby harmful stresses will be removed from the shell and none added to the head. From this bracket a rod would pass to the supporting beam above.

I recommend that all boiler users insist upon the three-point suspension, as it is the only scientific and safe method.

Size of Tubes in Horizontal Return Tubular Boilers.

It is a great mistake to make the tubes of horizontal return tubular boilers over 3 in. in diameter. By using larger tubes, less surface is provided in a given boiler, the gases are not split up in small streams and do not so well impart their heat to the boiler, and the gases have a better opportunity to utilize a part of the tubes. All of these things reduce efficiency. If the coal has a good deal of volatile matter the case is not altered, and the use of 4-in. tubes, which are employed west of the Hudson River, is a mistake. If small tubes are likely to become stopped by soot with western coal it is advantageous because it compels the tubes to be kept clean.

Height of Boilers above Floor.

There is a mistaken policy at present, of mysterious origin, of, in general, placing boilers very high. This is done for the purpose of obtaining room for combustion on the assumption that great room is necessary. It is overlooked that horizontal space, when such is available for gas travel, is as good as vertical, and the only boilers that lack in the former are water-tube boilers with transverse baffles. The only way to obtain combustion space in these boilers is to place them high, and I am inclined to think that they are responsible for the mania. I have earlier in this paper made some comments upon this.

With other types of boiler, such as the horizontal return tubular and horizontal water-tube boilers, the space is abundant for the best results, even with low settings. This is apparent when it is considered that the best combustion can be obtained in the furnaces of Scotch marine boilers, in which there is almost no vertical space and no great horizontal space, with the added assumed disadvantage that the fire and evolved gases are surrounded at close quarters with steel plates in contact with water.

If air can be admitted where it will penetrate the combustible gas the combustion will occur instantly. The narrower this space the more perfectly the necessary mixing will occur. For this reason it is apparent that the greater the elevation of boilers with horizontal gas travels the more uncertain the gas and air mixture becomes, and the more the boilers are elevated the less efficient the boilers are. It should not be forgotten that horizontal return tubular boilers when set low have low combustion space only at the center.

The elevation of the boilers with transverse baffles only to a slight extent improves the mixture, as currents are almost vertical and parallel and have but little opportunity to mix and burn. Elevating such boilers is only groping in the dark, and with most other types elevation is harmful. When, in connection with this, the extra cost of the brickwork and the greater opportunity for cracks, which admit air that does not support combustion and cools off the boiler, are considered, the harm of high settings is evident.

The best place to admit air to hand-fired boilers, especially with horizontal gas travel, is at the bridge wall, for the air then has the best opportunity to penetrate the combustible gases. There are devices on the market for doing this.

In the case of mechanical stokers, the above remarks concerning space apply, but with pulverized coal more space is required because the fuel moves; but here again horizontal space is as effective as vertical.

Height of Bridge Walls.

The height of bridge walls appears to be a matter of great uncertainty, as they are sometimes made low and sometimes high.

The main purpose of a bridge wall is to limit the fuel bed and to prevent the coal from being thrown over it. Many bridge walls in marine boilers are only 9 in. high, because the furnaces are small. They answer the purpose, and it is safe to say that no bridge wall need be over 12 in. high, or 15 in. at most. The bridge wall, so far as its height is concerned, does not assist in burning carbon to CO_2, which is the great object in view, and other considerations must therefore determine its height. A high bridge wall might project a great quantity of hot gas on a part of the boiler within which dirt has lodged, and thus cause overheating and injury. There is no doubt that if the combustion is complete the heat will be absorbed without being directed against a small part of the shell. If boilers are set very high, a high bridge wall may cause air to reach combustible gases that it would otherwise be unable to encounter, but I can see no other advantage.

The Vertical Fire-tube Boiler.

This type of boiler is used extensively in the New England States, and is an excellent form. It is not only an efficient evaporator but it superheats the steam from 15° to 40° F., depending upon the length of tubes exposed to the steam, and being an internally fired boiler is free from air leaks and is therefore not subject to this source of inefficiency. The steam can still further be superheated by means of the locomotive type of superheater.

The boiler suffers from having parallel vertical gas currents, and therefore needs careful firing. With such firing it gives excellent results.

A vertical tube absorbs heat throughout its circumference and is perhaps a better heat absorber than a horizontal tube. The tubes sometimes leak at the lower ends, but this can be prevented by welding them in, as is commonly done on locomotives.

Many persons think that there is an inherent lack of economy in such boilers, the argument being that as the tubes are vertical the gases rapidly pass out and do not leave their heat behind. This is a superficial view and has no scientific foundation. The truth of the matter is that the damper is opened sufficiently to burn the amount of coal necessary to produce the desired amount of steam in a unit of time, and as a result a certain number of cubic feet of gas pass through the tubes in that time. This fixes their velocity and they can move no faster than if they passed through horizontal tubes.

An important thing in connection with this type of boiler is usually neglected, viz., air-tight smoke-box construction. The smoke box should be the extended shell, or a shell tightly riveted or bolted to the boiler. If this is attended to, the escaping gases will be hotter than in boilers set in brickwork. This is true of other internally fired boilers, such as the locomotive and Scotch. This is important where economizers are used, to say nothing of conservation of chimney draft.

Another advantage of this boiler is that less draft is required than with other types, which is probably due to its acting at right angles to the fuel bed, the air thus encountering less resistance.

I have made two designs of vertical boilers with corrugated fire boxes such as are used for the furnaces of Scotch marine boilers. By this means the use of staybolts is avoided. This I consider the best way to design vertical boilers. The inside minimum diameter of such furnaces is limited to 6 ft., but the diameter of the grate can be 3 in. larger.

Locomotive Type Boilers.

This type of boiler is one of the best, and always gives economical results. It can be made from very small to very large sizes, and to carry any pressure. The Pennsylvania Railroad has a locomotive with a boiler having a maximum diameter of 110 in., a total length of 53 ft. 9½ in., a

maximum thickness of plate of $1\frac{5}{16}$ in., a water-heating surface of 6 656 sq. ft., superheating surface of 3 136 sq. ft., and carries a pressure of 225 lb. They also have boilers carrying 250 lb. The only limit in size to this type is the ability to transport it.

The locomotive type of boiler presents an opportunity to use a brick arch which is used in most locomotives. This lengthens the path of the gases, which otherwise would be very short, and presents an opportunity for the air which passes through the fire door to mingle with the gases and burn any CO which may be escaping, to CO_2. I think that it is hardly an exaggeration to say that the locomotive type of boiler provided with a brick arch is the most economical of all boilers.

The objections to the boiler are its cost and the depth of the boiler house required to provide room to clean or remove the tubes, as it is best to do this under cover.

Forcing Capacities of Boilers.

Boilers do not differ much in this respect. Any boiler can be forced to an unlimited extent if the necessary fuel can be burnt. Underfeed stokers usually have fan capacity enough to force boilers beyond usual rates, but all kinds of boilers, whether fire or water-tube, are capable of this forcing. Rapid steaming of boilers does not depend upon the amount of water which they contain, after the water is once heated to the temperature of the steam, as further heat can only make steam. It depends upon the quantity of fuel burned in a unit of time, and the perfection with which the hot gases circulate among the heating surfaces. Fire-tube boilers excel in the latter respect. Of all boilers, the locomotive type of boiler on locomotive is forced most. The tubes of water-tube boilers are no better heat absorbers than those of fire-tube boilers, and probably not as good if the path of the gases is transverse to the tubes.

High Boiler Pressures.

Both fire- and water-tube boilers can be made for very high pressures, the former, say, up to 350 lb., and the latter somewhat beyond if the risk of tube explosions is ignored.

Reduction of Pressure from Age.

It is customary to reduce the pressure of fire-tube boilers after a time, on general principles. There is as much reason for reducing it on water-tube boilers, and if there are no apparent defects there is no reason for reducing it on either, except for the possibility of hidden defects. When a serious reduction of pressure is contemplated, or when a boiler is to be condemned, it would be best to remove a sufficient number of tubes, and

even to remove the butt straps, to enable a complete examination to be made. If no serious defects can be found, these parts should be replaced and the boiler continued in service and considered as good as new.

The Safety of Boilers.

Boilers, if designed with butt longitudinal joints having all rivets in double shear, and with no parts so made that they will bend when subjected to strain, are as safe as any structure if they are kept clean and free from corrosion. The causes of explosions of water tubes are being investigated, and there is evidence that a harder and stiffer steel than has heretofore been used is advantageous.

Rivet Heads.

It is customary for boiler makers to use conical rivet heads, known as "steeple heads." This is a relic of the past which seems to have escaped the notice of most boiler makers. Nobody would think of making any other part of a mechanical structure like this, that is to say, one with slanting sides coming down to a knife edge. It would be bad construction, and it is no better when it is a part of a boiler. It is bad because the holding power of the rivet diminishes to nothing toward the edge, it has no edge to calk when this is necessary, and needs calking oftener than other forms.

The so-called "button head" is free from the above defects. It is used exclusively by the American Locomotive Company, the Baldwin Locomotive Works, the Pennsylvania Railroad, and all leading makers of marine boilers.

The button head should be required by all specifications.

Water Glasses and Gage Cocks.

In the United States it is customary to equip each boiler with one set of gage cocks and one water glass for showing the height of the water. I prefer to have two water glasses and no gage cocks, as the latter are seldom used and the former provide two means of observation of the height of the water.

Feed-water Regulators.

It is becoming a growing custom in this country to use feed-water regulators on boilers. There are several makes and they simultaneously control the admission of water and the speed of the pumps. They have proved to be reliable and maintain a steadier water level than is otherwise possible, especially in a large plant.

Superheaters.

Superheated steam is commonly used in many steam plants. It economizes steam in an engine by reducing cylinder condensation. Although it requires heat to superheat the steam, which might be used for evaporating water in the boiler, there is an important net gain by the use of such steam. The saving in steam used by an engine amounts to about one per cent. for every 10° F. of superheat. Superheaters can be applied to most boilers.

Very high superheat is troublesome on account of distortion of valves and some other parts, but 150° F. is safe, with ordinary pressures.

Soot Blowers.

An objection to water-tube boilers has been that the tubes could not well be effectively cleared of soot. Within a few years, however, blowers have been devised, and are now commonly used, by which the soot can be blown off more effectively than heretofore. As before stated, the use of horizontal baffles and hollow staybolts in boilers with headers promote this. All boilers, whether water-tube or fire-tube, should be equipped with soot blowers, and required by the specifications. Their use is advisable as they produce a real economy in coal, are easily and quickly used, and are more likely to be used in consequence.

In one of the Emergency Fleet boilers, which was provided with electrical temperature-recording apparatus, the tubes were blown every two hours during some tests, and the temperature of the escaping gases fell 35° F. each time, when hand-fired. With the same boiler, when stokers or oil were used, there was no drop in the temperature at the two-hour intervals, and the blowing was afterwards done less frequently.

Temperature of Escaping Gases.

It is difficult to ascertain the temperature of the escaping gases from a boiler, because it differs in different parts of an uptake, and to find the position of average temperature is a matter of guesswork. Moreover, samples of gases differ in composition from different parts of an uptake.

Mechanical Stokers.

In many situations the efficiency of a hand-fired boiler when skillfully fired equals that with a mechanical stoker, and when allowance is made for the steam used by the stoker will surpass it. There is no opportunity in most pumping stations for mechanical stokers. Their fields lies where they can reduce the cost of labor.

The prevailing type of mechanical stoker is the underfeed, which is made in several ways. They require to be driven by power, and considerable power is required to blow the air.

Pulverized Coal.

Pulverized coal has been known for several years as a desirable form of fuel, but the difficulty, now overcome, has been to pulverize the coal to sufficient fineness. It is desirable that this should be such that at least 85 per cent. of it shall pass through a mesh of 200 per inch. Some pulverizers even surpass this with most kinds of bituminous coal.

When this kind of fuel is used it is blown into an empty furnace with the proper quantity of air, and flashes into flame when the furnace is incandescent. As it is a moving fuel it requires considerable volume for combustion. Every little particle of coal is accompanied with air in but slight excess, and as a consequence more perfect combustion, which is smokeless, results than by any other means. Any kind of coal can be used, and coal that cannot be used either by hand or stoker firing can be used as well as the best.

As no part of the mechanism is exposed to heat, it is evident that the maintenance cost is very low compared with that of stokers. Moreover, the complication of a stoker is done away with.

There are two general systems of producing and burning pulverized coal, one in which the coal is first dried, then pulverized, then blown into a storage bin, then conveyed to the vicinity of each boiler, where it is taken by a so-called burner, and blown into the furnace, and another in which the coal is neither dried nor pulverized in advance, and which has no burner. The pulverizer in the latter case delivers the coal into the furnace and is operated only when the boiler is in service.

By means of pulverized coal the boiler performance is continuous, and the fire does not require cleaning.

Hand Stokers.

There are now on the market so-called hand stokers which only require the coal to be placed on the end just inside of the fire doors. By means of a lever the bars of the stoker, which are transverse to the depth of the furnace, are rotated and advance the coal toward the bridge wall, the last bar dumping the ash and clinker into the ash pit. No cleaning of the fire is necessary, and the steaming of the boiler is nearly continuous. As the coal is placed only on the front of the grate the smoke is diminished in consequence of the gases which are first liberated passing over incandescent coal. This maintains their temperature, and if sufficient air is admitted the smoke is reduced. It is obvious, however, that it is still possible with it to admit too little or too much air, and easy to dump too much combustible matter at the end.

Oil Fuel.

Oil is an ideal fuel for boilers because it is easily handled, requires minimum attendance, and produces no ashes. It should not, however, usually be employed for land boilers, because its best field is for ocean service, is so necessary for lubricants and other purposes, and because its occurrence in nature is so uncertain, if not insufficient.

It can be burnt without smoke, but if I am to judge from appearances the smokiest chimneys in Boston are those from oil-burning boilers.

Mechanical atomization is preferable to steam, because in the latter case it is very easy to waste steam, and there are no easy means of determining when the waste occurs.

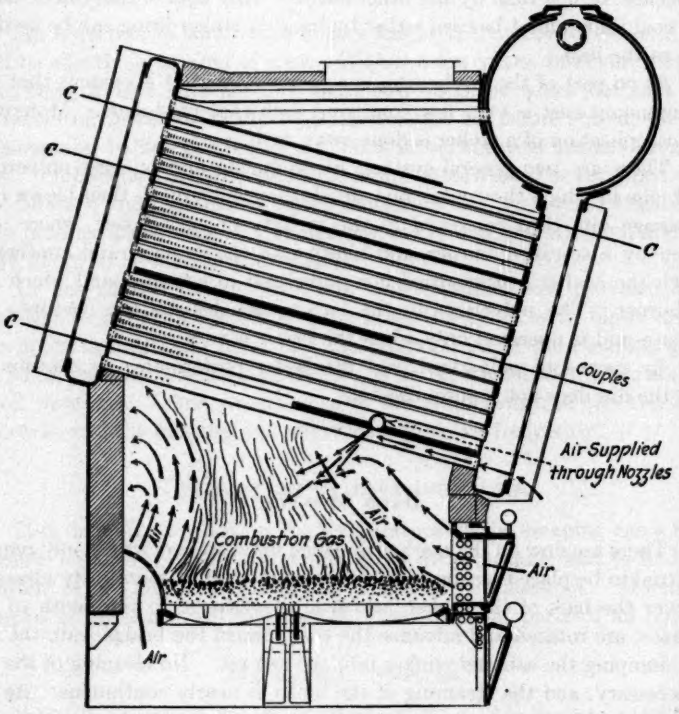


Fig. 1.

Grate Bars.

Grate bars are made both fixed and shaking. The latter are not necessary for the best results and can easily be a means of wasting coal by too much agitation. The labor of cleaning fires is reduced by the use of shaking bars, and in the effort to avoid this labor they may be shaken so

much as to be wasteful. In most cases fixed grates are advisable. In cases where it is the policy to force boilers, shaking bars are best.

Bars for bituminous coal should in general have 50 per cent. of air space, and the iron and air spaces should each be ½ in. wide. The parts in contact with the coal should be rounded on top and so formed that the air can have access as much as possible to the whole under side of the coal,

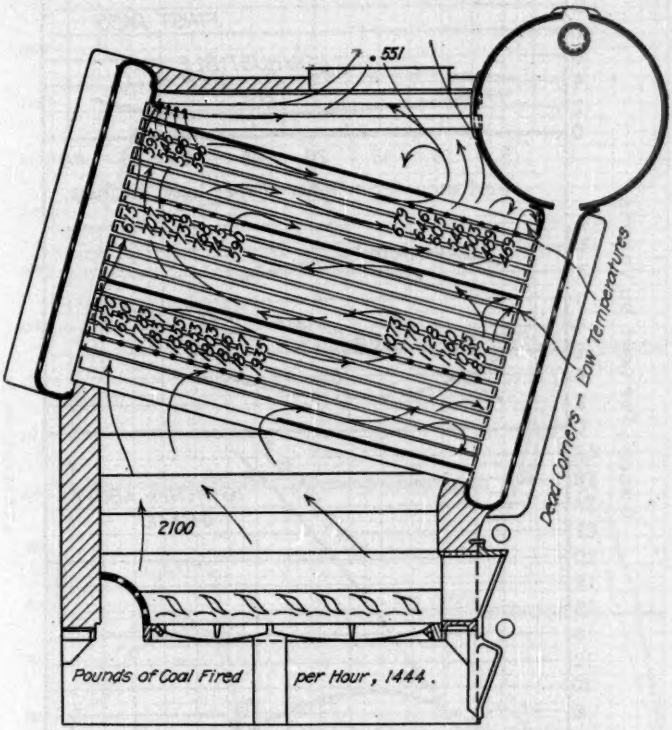


FIG. 2.

except where the coal actually touches the grates. There are such bars on the market, and the air spaces amount to virtually almost 100 per cent. It is not possible to have too much air space, and even with the maximum, the formation of CO cannot be prevented except by air admission elsewhere.

Shaking grate bars are of little use with coal that forms a continuous tenacious slab of clinker over the grates, as they only scrape the bottom of such clinker, and the slice bar is still an important tool.

FEEDING BOILERS.

Boilers are fed by pumps or injectors. If there is exhaust steam available for heating the feed water, pumps and a heater should be used. If there is no exhaust available, injectors should be used. The reason for

this is that any kind of piston engine, such as a steam pump, condenses a large part of the steam in its cylinder, and therefore only a part of the steam used is available for heating, while with the injector all of the heat in the

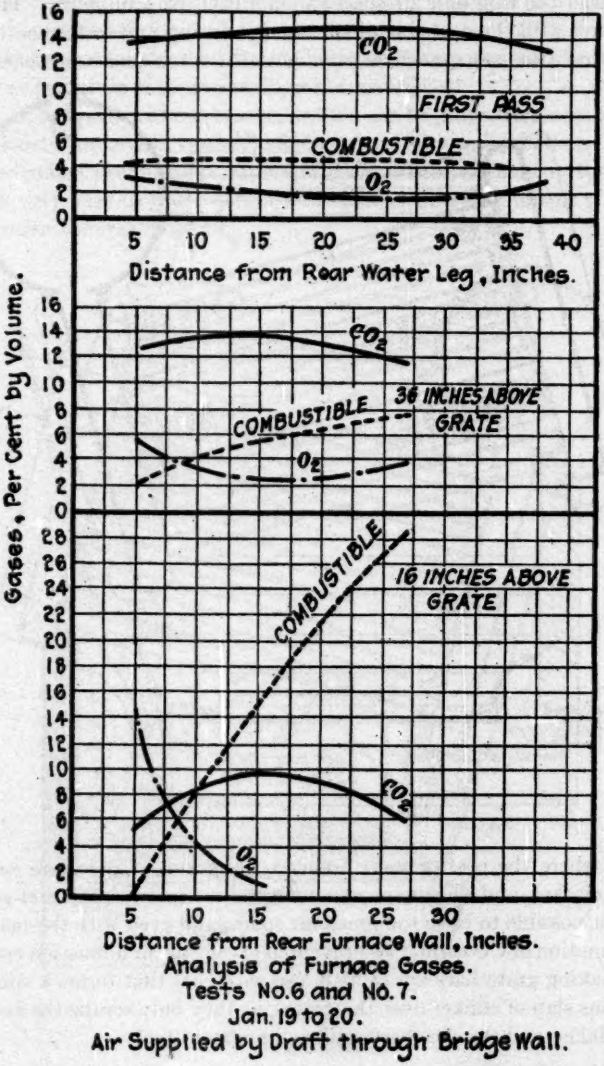


FIG. 3.

steam is returned to the boiler, except a very little which is used in starting the injector and in pipe condensation. Exhaust steam should not be made for the sake of using it.

Notes Concerning Some of the Results of the Tests of the Emergency Fleet Boiler for Wood Ships.

Two of these boilers, one 3-pass and one 4-pass, were subjected to exhaustive tests on land, and the following notes refer to the 4-pass boiler.

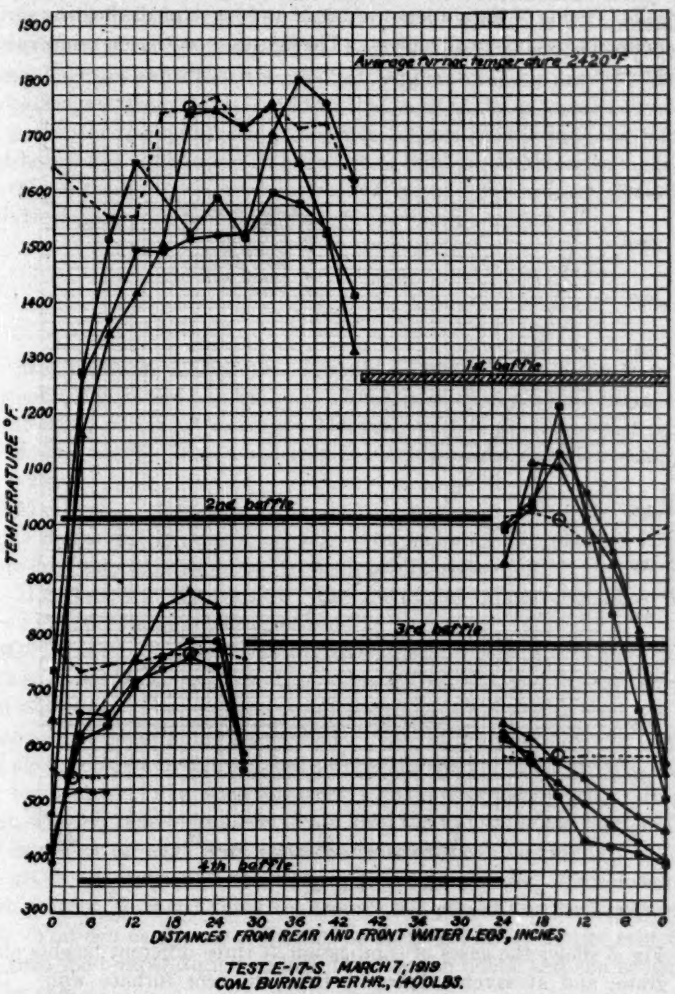


Fig. 4.

Fig. 1 shows the boiler in outline with air being introduced at the back of the grate, through and around the fire doors, and through perforations in a pipe above the lowest row of tubes. The latter arrangement was

not used during the tests to which the notes refer, but the other arrangements were.

Fig. 2 shows the paths of the gases among and around the baffles, as plotted from temperatures, taken by means of thermocouples, and drafts. The thermocouples and draft gage pipes were inserted through hollow staybolts. Some of the corners were dead and much of the heating surface was ineffective, as it is in all boilers. The figures show the gas temperatures in degrees F.

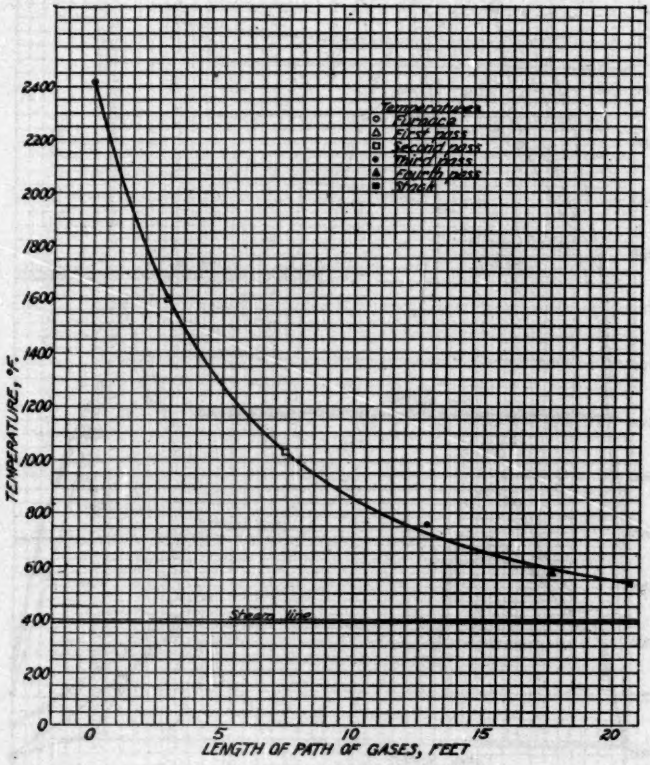


FIG. 5.

Fig. 3 shows the gases of combustion at three different heights above the grate, and at several distances from the rear furnace wall. They show how rapidly combustible gases are consumed and CO_2 formed when air is admitted at the proper place. From this it is evident that the large furnaces about which we hear so much are unnecessary, at least with good semi-bituminous coal such as was here used. The rate of combustion was about 20 lb. per sq. ft. of grate per hour.

Fig. 4 shows furnace and gas temperatures throughout the tubes and baffles as given by thermocouples. The lowest baffle is at the top of the diagram in order to be properly related to the high temperatures in its vicinity. The dotted line gives temperatures of a fixed thermocouple in the positions indicated by circles. These were read simultaneously with the movable thermocouples, in order to have means of determining as well as possible the effect due to the heat developed as well as to position. These diagrams show that the greatest temperatures are near the ends of the baffles, and from this it is evident that most of the gases take the shortest paths and pass close to these ends. From this it may be inferred that horizontal baffles may be longer than they are customarily made.

Fig. 5 shows the manner in which the gas temperatures fall in their path throughout the boiler from the firebox to the uptake.

Discussion.

Mr. Richard A. Hale.* I would like to ask Mr. Dean if in this oil combustion, where you get such intense heat, there is an injurious effect on the boiler plates by burning? Does any part of the rivet sheet receive any intense heat? I was wondering whether it burned the plate or injured the boiler.

Mr. Dean. I do not think that there would be trouble from this source unless dirt is present on the water sides of the plates. Riveted joints are frequently subjected to the heat of combustion.

Mr. Henry J. Williams.† Has the fluxing of pulverized coal when blown into the furnace been overcome?

Mr. Dean. Yes, it has been overcome. There is a furnace which has a so-called water jacket and has tubes in the sides, and they are covered with box tiles. The temperature of the sides is reduced so that the slag usually drops down before it gets there. That is, it drops down as a powder. It is also overcome by introducing air into the sides of the furnace to reduce the temperature. In such furnaces without the water-jacket arrangement, which is quite expensive, if you keep the CO_2 to 14 per cent. and less and introduce air slightly at the sides, you will have no trouble. All you will get in the bottom of the furnace is a light powder, which looks like tooth powder, so that I think the trouble has passed now with pulverized coal. You can easily run a furnace so as to get 16 or 17 per cent CO_2, and then the temperature is so high that the ash melts, and can be caught in slag cars.

Mr. A. O. Doane.‡ Would it be advisable to put pulverized coal or oil fuel into a vertical boiler?

---

* Principal Assistant Engineer, Essex Co., Lawrence, Mass.
† Fuel Engineer, Boston.
‡ Division Engineer, Metropolitan Water Works, Boston.

MR. DEAN. You cannot use pulverized coal in a vertical boiler unless you have an enlarged furnace, because you have not the length of travel sufficient to give it a proper length of time to be consumed. Oil, however, does not require so much volume, and is used in vertical boilers considerably.

MR. EDWARD D. ELDREDGE.* What is the cause of the situation that we sometimes see when the CO escapes from the top of the uptake and is not burned until it reaches the atmosphere?

MR. DEAN. CO is always formed in a furnace to some extent, and if the firing is very poor you cannot get sufficient oxygen into the gases to complete combustion. If one part of oxygen joins with the carbon you have a partially burned gas, which is still capable of being burned if an additional part of oxygen comes in contact with it. Now, that gas can go up through the boiler, and sometimes its temperature is high enough to burn if oxygen gets to it, and it often does, through leaks in the uptake.

I remember seeing on Moosehead Lake a steamer, some years ago, that had a stream of flame from the stack, caused in this way. I also once saw a locomotive on the Erie Railroad with flame issuing from the stack. That used to be the regular thing, quite a good many years ago, on steamers going from Liverpool and Holyhead over to Ireland. It was a mystery for a long time, but they finally found out that it was due to insufficient air.

On the Pacific Coast, when the first wood ship was started with the Emergency Fleet boilers, they had that trouble. They could not make any speed on the trial trip, but they secured an expert in San Francisco, who understood the situation at once. He told them to leave the fire doors wide open, and when they did that the boiler immediately improved in performance. Of course that was overdoing the matter, but it stopped the trouble. Later he made an arrangement for admitting air above the fire, and the boilers then worked perfectly well.

* Superintendent, Water Works, Onset, Mass.

PROCEEDINGS.

Annual Meeting.

Boston City Club,
Thursday, January 12, 1922.

The President, Mr. Charles W. Sherman, in the chair.

The President. In accordance with the requirements of the Constitution, the time for filing ballots for officers for the ensuing year ends now. If anyone has a ballot that has not yet been cast and cares to cast it now, he may pass it in to the Secretary; if not, I shall declare the ballot closed. Are there any others? (No response.) The ballot is closed.

Since our last meeting the Association has suffered severely by death. We have lost a man who was practically always present at the meetings, whom all of us knew and liked, and who has done an immense amount of work for the Association, although he did not hold personally a membership, being a representative of an associate member. I refer, as most of you gentlemen probably realize, to our late friend, Thomas E. Dwyer, whose death occurred a short time ago.

We have also lost one of our past presidents and an honorary member of the Association, — George A. Stacy of Marlborough.

I will ask the members to stand in silence for a moment in memory of these friends.

(Everybody stands.)

The following were duly elected members of the Association:

Active: Allen F. McAlary, Superintendent Camden & Rockland Water Co., Rockland, Maine; Arthur Daniels Weston, Principal Assistant Engineer, Engineering Division, Massachusetts Department of Health.

Associate: Metalium Sales Co., 50 Broadway, Providence, R. I.

The President. The next business before us is action upon the proposed amendment to the Constitution, which was reported to the last meeting and recommended by the Executive Committee, as follows:

"Amend Section 2, Article 8, by striking out the word 'Wednesday' and inserting the word 'Tuesday' in place thereof, so as to read:

"Section 2, Article 8. There shall be two general business meetings of the Association each year: first, the annual meeting, which shall be held in Boston on the second Tuesday in January, and at which the annual reports for the year ending December 31 shall be presented and

the ballot for officers canvassed; and second, a business meeting during the annual convention.

"Amend Section 3, Article 8, by striking out the word 'Wednesday' and inserting the word 'Tuesday' in place thereof, so as to read:

"Section 3, Article 8. In addition to the above, business meetings shall be held on the second Tuesday of the months of November, December, February and March, and, at the discretion of the Executive Committee in June."

This proposed change in our meeting day from Wednesday to Tuesday is in order to make it possible for us to continue to come here to the City Club if it shall prove acceptable to the membership as a whole, as I judge from appearances it has so proved today. We cannot come here on the second Wednesday, our old date, under any circumstances, as the Rotary Club has the Club facilities engaged for an indefinite time in the future on the second Wednesday of each month, consequently it requires some change, and it seemed to the Executive Committee in suggesting this amendment that Tuesday would be equally acceptable to the Association and it would make it possible for us to come here, or, of course, if that is not satisfactory, to go anywhere else just as much as on Wednesday. Is there any discussion on the proposed amendment?

MR. GEORGE A. KING. I do not know whether this need affect the present amendment, but it has been my opinion, and from my experience as President I believe that the annual meeting should be held at the convention, and that the year should begin at the close of the convention in September. As it is today, the President cannot form any policy for the organization, coming in as he does in the middle of the term of our activities, but a man coming into office say the first of October would have a chance to formulate a policy for the winter and have an opportunity to carry it out. As it is today, we have our election in January and probably the Executive Committee will not meet until February. Then there is only one meeting more before the close of our winter meetings, then there is a long vacation and we meet again in September, and there are only the meetings in November and December after the convention, and the President lets things slide as a general rule. I think it would be much better for the Association and much better for the President who has something in his mind he would like to carry through, to have the election say the first day of the convention and have the new officers take office in October. I doubt if we could pass on that at this meeting with this short notice, but that is something I have advocated, and when the Committee on Revision of Constitution a year or two ago asked for suggestions that was one of those which I made.

THE PRESIDENT. I think the point is very well taken, Mr. King. I also think that your point of order that we cannot act on this today is also correct. For your information and that of the membership, I want to say that the Committee on Revision of Constitution to which you refer

is still in existence and has practically completed its labors. I am informed that it has a proposed revised form of constitution now drafted which will be submitted to the Association at a very early meeting, and if I understand correctly it would mean a pretty radical revision of the whole constitution, and I may perhaps be permitted to say that I think it is about time.

Is there any other discussion? (No response.)

(The question was put and the amendment to the Constitution unanimously adopted.)

The following reports of the officers of the Association were received:

Report of the Secretary.

January 3, 1922.

Mr. President and Gentlemen of the New England Water Works Association, — The Secretary submits herewith the following report of the changes in membership during the past year, and the general condition of the Association.

The present membership is 828, constituted as follows: 10 Honorary, 742 Active, and 76 Associate Members, there being a net loss for the year of 44. The detailed changes are as follows:

MEMBERSHIP.

January 1, 1921.	Honorary Members	14			
	Died	4			10
January 1, 1921.	Total Members			788	
	Withdrawals:				
	Resigned		39		
	Dropped		31		
	Died		10	80	
			—	—	
				708	
	Initiations:				
	January		4		
	February		2		
	March		4		
	June		4		
	September		12		
	November		2		
			—	28	
	Reinstated:				
	Members resigned in 1917		1		
	Members dropped in 1919		3		
	Members resigned in 1920		1		
	Members dropped in 1920		1	6	742
			—	—	
January 1, 1921.	Total Associates			70	
	Withdrawals:				
	Resigned		1	1	
			—	—	
				69	

Initiations:			
February	1		
September	4	5	
Reinstated:			
Associate resigned in 1918	1		
Elected in 1920, qualified in 1921	1	2	76
January 1, 1922. Total membership			828
January 1, 1921. Total membership			872
Net loss			44

Members Elected in 1921.

January. Bernard S. Coleman, Roger W. Esty, Charles A. Hatch, Alexander H O'Brien. (4)
February. Harry W. Dotten, Spencer W. Stewart. (2)
March. Walter F. Abbott, Clarence E. Carter, Harry C. Kerr, August G. Nolte. (4)
June. D. H. Hall, Albert E. Lavery, F. E. Hammond, E. R. Conant. (4)
September. Harry E. Collins, Donald M. Hatch, Benjamin H. Keeler, Jr., William A. Megraw, S. John Scacciaferro, Henry L. Shuldner, John O. Taber, Jr., R. H. Blanchard, Ivan Escott, R. F. Johnson, Frank N. Strickland, George C. Ham. (12)
November. John C. Adams; Fred W. Young. (2)
December. Alfred Bétant. (1) *Did not qualify up to December 31, 1921.*

Reinstated:	
Resigned in 1917 (L. E. Thayer)	1
Dropped in 1919 (F. H. Gunther, John J. Philbin, G. Z. Smith)	3
Resigned in 1920 (F. W. Dean)	1
Dropped in 1920 (Allston F. Hart)	1
	6

Associates.

February. Ambursen Construction Company, Inc. (1)
September. Continental Pipe Mfg. Company, Linus G. Read, Payne-Dean Ltd. (3)

Reinstated:	
Elected 1920, qualified 1921, (Lawrence Machine Company)	1
Resigned in 1918 (Am. Manganese Bronze Company)	1
	2

Resigned:
Public Works. (1)

Honorary Members.

Died: Hiram F. Mills, William T. Sedgwick, Fred W. Shepperd, George A. Stacy. (4)

Members.

Died: Samuel M. Gray, Charles E. Haberstroh, E. L. Hatch, S. S. Hatch, R. A. McKim, William M. Stone, Richard L. Tarr, Samuel E. Tinkham, Albert H. Wehr, Charles W. Young. (10)

Receipts for 1921.

Initiation fees			$178.00
Annual dues:			
Members	$4 444.02		
Associates	1 440.00	$5 884.02	
Fractional dues:			
Members	$45.00		
Associates	25.00	70.00	
Past dues		21.08	
Total dues			$5 975.10
Advertising			3 120.77
Subscriptions			390.00
JOURNALS sold			140.73
Sundries			191.94
Total receipts			$9 996.54
There is due the Association:			
Advertisements			$551.00
Reprints			24.00
JOURNALS			7.50
Total			$582.50

Respectfully submitted,

FRANK J. GIFFORD, *Secretary.*

REPORT OF TREASURER.

CLASSIFICATION OF RECEIPTS AND EXPENDITURES.

Receipts.

Dividends and interest		$190.04
Initiation fees	$178.00	
Dues	5 975.10	
Total received from members		$6 153.10
JOURNAL:		
Advertisements	$3 120.77	
Subscriptions	390.00	
JOURNALS sold	140.73	
Sale of reprints	101.69	
Cuts sold	10.83	
Total received from JOURNAL		$3 764.02

Miscellaneous:		
Sale of "Pipe Specifications"	$40.25	
Membership lists	5.00	
Buttons	2.25	
Certificates of membership	7.50	
Meter rate sheets	4.25	
Exchange	1.00	
American Water Works Association	10.23	
Total miscellaneous receipts		$70.48
Total receipts		$10 177.64

Expenditures.

JOURNAL:		
Advertising agent's commission	$226.10	
Plates	4.33	
Printing	4 493.08	
Editor's salary	300.00	
Editor's expense	7.56	
Reporting	326.30	
Reprints	453.66	
Envelopes and postage	74.78	
		$5 885.81
Office:		
Secretary's salary	$200.00	
Assistant Secretary's salary	1 080.00	
Assistant Secretary's expense	54.94	
Rent	750.00	
Printing, stationery, and postage	354.72	
Membership lists	304.30	
Telephone	14.21	
		$2 758.17
Meetings and Committees:		
Stereopticon	$50.10	
Dinners for guests	24.70	
Music	1.50	
Printing, stationery, and postage	166.62	
Badges	62.50	
Miscellaneous	52.23	
		$357.65
Treasurer's salary and bond		67.50
Certificates of membership		2.50
Miscellaneous		86.21
		$9 157.84

LEWIS M. BANCROFT, *Treasurer*.

In account with the New England Water Works Association.

RECEIPTS.			EXPENDITURES.		
1921.			Bills paid		$9 157 84
Jan. 1. Balance on hand		$1 435.17	BALANCE ON HAND		
Received of F. J. Gifford, Secretary		9 996.54	Coupons	$40.00	
Interest on bonds and deposits		181.10	First National Bank	658.85	
			Liberty Trust	523.50	
			Mechanics Savings	232.62	
			People's Savings	1 000.00	2 454.97
		$11 612.81			11 612.81

ASSETS AND LIABILITIES.

ASSETS.			LIABILITIES.	
Cash balance in banks		$2 454.97	Surplus	$4,852.47
Bonds Nos. 2642 and 2644 Lake Shore & Michigan Southern R. R. 4s, due 5–1–1931.		1 815.00		
Accounts receivable:				
JOURNAL	$7.50			
Reprints	24.00			
Advertising	551.00	582.50		
		$4 852.47		$4 852.47

READING, January 12, 1922.

LEWIS M. BANCROFT, *Treasurer*.

Report of Auditing Committee.

January 6, 1922.

We have examined the accounts of the Secretary and Treasurer of the New England Water Works Association, and find the books correctly kept and the various expenditures of the past year supported by duly approved vouchers. The Treasurer has also accounted to us for the investments and cash on hand, as submitted in the above report.

GEORGE H. FINNERAN,
FRANK A. MARSTON,
Finance Committee.

Report of the Editor.

January 12, 1922.

To the New England Water Works Association: I present the following report for the Journal of the Association for the year 1921.

As has been the custom, the figures presented are for Volume XXXV rather than the calendar year of 1921, and represent total charges and accounts paid and payable rather than actual cash received or disbursed.

The accompanying tabulated statements show in detail the amount of material in the Journal.

Size of Volume. — The volume contains 560 pages, an increase of 40 pages from that of 1920.

Reprints. — Twenty-five reprints of each paper have been furnished to the author without charge.

Circulation. — The present circulation of the Journal is:

Members, all grades	828
Subscribers	86
Exchange	15
Total	929

a decrease of 41 from the preceding year.

Journals have been sent to all advertisers.

Advertisements. — There has been an average of 31½ pages of paid advertisements, with an income of $2 921.68, an increase of $162.33 over last year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $15.25 have been sold. The net gain up to a year ago had been $322.10 so that total net gain from this source to date is $337.35 and 84 copies of specifications on hand, — $21.00 worth if sold at retail.

Post-Office Accounts. — The Association has a credit of $2.15 at the Boston Post Office, being the balance of money deposited for payments of postage.

Meter Rate Sheets to the value of $4.25 have been sold during 1921.

TABLE I.

STATEMENT OF MATERIAL IN VOLUME XXXV JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1921.

Date.	Pages of								
	Papers.	Proceedings.	Total Text.	Index.	Advertisements.	Cover and Contents.	Insert Plates.	Total.	Total Cuts.
March	57	33	90	0	35	4	0	129	9
June	60	54	114	0	37	4	0	155	5
September	91	1	92	0	35	4	0	131	6
December	86	17	103	3	35	4	0	145	9
Total	294	114	399	3	142	16	0	560	29

TABLE 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XXXV, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1921.

Receipts.		*Expenditures.*	
Advertisements	$2 921.68	Advertising agent's salary and commission	$254.30
Sale of JOURNALS	140.73	Plates	4.33
Sale of reprints	48.75	Printing	3 997.01
Subscriptions	390.00	Mailing postage	77.58
Sale of cuts	10.83	Editor's salary	300.00
		Editor's incidentals	7.82
		Reporting	326.30
		Reprinting	414.50
	$3 511.99		
Net cost of JOURNAL	1 869.85		
	$5 381.84		$5 381.84

Respectfully submitted,

HENRY A. SYMONDS, *Editor.*

TABLE 3.

COMPARISON BETWEEN VOLUMES XXV TO XXXV, INCLUSIVE (OMITTING VOLUME XXXI), NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. XXV. 1911.	Vol. XXVI. 1912.	Vol. XXVII. 1913.	Vol. XXVIII. 1914.	Vol. XXIX. 1915.	Vol. XXX. 1916.	Vol. XXXII. 1918.	Vol. XXXIII. 1919.	Vol. XXXIV. 1920.	Vol. XXXV. 1921.
Average edition (copies printed)	1 000	1 000	1 000	1 050	1 325	1 500	1 388	1 200	1 150	1 100
Average membership	752	740	745	803	904	1 002	954	902	885	864
Circulation at end of year	840	826	858	951	1 079	1 155	1 010	1 002	970	929
Pages of text	475	401	554	564	596	538	398	566	359	399
Pages of text per 1 000 members	632	542	746	702	659	538	417	627	406	462
Total pages, all kinds	654	567	733	719	776	707	557	726	520	560
Total pages per 1 000 members	870	766	984	895	859	707	584	805	588	648
GROSS COST:										
Total	$2 625.87	$2 476.55	$3 586.29	$3 345.87	$4 243.35	$3 386.63	$3 115.00	$4 967.99	$5 011.03	$5 381.84
Per page	4.02	4.37	4.89	4.65	5.47	4.79	5.59	6.84	9.64	9.61
Per member	3.50	3.35	4.81	4.17	4.68	3.38	3.26	5.51	5.66	6.23
Per member per 1 000 pages	4.09	5.90	6.46	5.80	6.02	4.79	5.85	7.59	10.88	11.12
Per member per 1 000 pages text	7.36	8.35	8.68	7.39	7.85	6.30	8.19	9.74	15.77	15.61
NET COST:										
Total	$352.82	$98.81	$1 322.90	$1 155.33	$2 091.09	$1 171.98	$694.50	$2 675.04	$1 722.14	$1 860.85
Per page	.54	.17	1.80	1.61	2.70	1.65	1.25	3.68	3.31	3.34
Per member	.47	.13	1.78	1.44	2.32	1.17	.73	2.97	1.95	2.16
Per member per 1 000 pages	.55	.23	2.42	2.00	2.98	1.65	1.31	4.09	3.75	3.87
Per member per 1 000 pages text	.98	.33	2.38	2.55	3.88	2.17	1.83	5.25	5.43	5.43

MR. SYMONDS. Now, if I may be permitted, I would like to say a word informally. The advertising agent has an obligation to the Association to enlarge the business of the Advertising Department, to make the Journal advertising pay as large a return to the Association as possible. The advertising agent also has another obligation which is as great as the first, which is to see that the advertisers in the Journal are getting what they are paying for, that the value of the advertising is made good. Now, gentlemen, that is something which is to a very great extent up to you. When it is claimed, as it has been in times past in this Association, that the advertising was sort of a bonus paid the Association by the advertisers, if when you get your Journals you pay no attention to the advertising section, if when you get ready to purchase you forget that the advertisers in the Journal represent nearly every line of water works supplies, equipment and experts through a great number of leading firms, then you are making that statement absolutely good and we have no argument with it, for in that case, as a commercial proposition, the ads. are of no value.

Now, gentlemen, that is not a satisfactory condition for the advertisers nor for the Association, nor do I believe it is true at this time, but as the Journal should be, and has the advantages to make it, the best advertising medium for all water-works supplies of any of that kind that I know of, it rests with you, gentlemen, to say whether by your interest in this department of the work it shall be made so. If it can be made so and the advertising agent can go with a full belief, conscientiously, to prospective advertisers with this claim and something behind it, there is a prospect that we can greatly advance the income from this source, the value to the Association, and the general interest in the work of the Association. There are many sides to this particular question which I believe it is for your interest to consider.

Now, I may weary you at times by harping on this particular matter, but I believe it is my duty, and yours, to take a new interest in this department of the work and see if we can't build up a better and larger Journal, a better Association through larger income, and greater interest in the general work of the Association.

I thank you. (Applause.)

(On motion, duly seconded, it was voted that the report of the Editor be received and placed on file.)

THE PRESIDENT. I hope that the informal remarks by Mr. Symonds will sink in and be borne in mind by everybody in a position to do so.

The next business is the report of the Tellers on the election.

REPORT OF TELLERS, JANUARY 12, 1922.

Whole number of ballots	300
Blanks	0
President.	
FRANK A. BARBOUR	293
Scattering	1
Vice-President.	
PATRICK GEAR	295
GEORGE A. CARPENTER	295
REEVE J. NEWSOM	293
DAVID A. HEFFERMAN	292
FRANK E. WINSOR	294
THEODORE L. BRISTOL	292
Scattering	1
Secretary.	
FRANK J. GIFFORD	288
Treasurer.	
FREDERIC I. WINSLOW	296
Editor.	
HENRY A. SYMONDS	297
Advertising Agent.	
HENRY A. SYMONDS	299
Additional Members of Executive Committee.	
GEORGE H. FINNERAN	298
FRANK A. MARSTON	298
MELVILLE C. WHIPPLE	299
Scattering	1
Finance Committee.	
A. R. HATHAWAY	295
EDWARD D. ELDREDGE	295
STEPHEN H. TAYLOR	294
Scattering	1

GUY C. EMERSON,
JAMES W. KILLAM,
JAMES A. McMURRAY,
Tellers

On motion of Mr. H. V. Macksey, duly seconded, it was voted that the above reports be accepted and placed on file.

THE PRESIDENT. You have all heard the report, gentlemen, by which it appears that the persons named by the Nominating Committee have been elected. While it is not, of course, necessary to turn the meeting over to the new officers, they not taking control until the next meeting, I think the members will want to hear a few words from the President elect. I will call on Mr. Barbour. (Applause.)

Remarks by President elect F. A. Barbour

Mr. Barbour. Mr. President and fellow members, I sincerely thank you for my election. It is an honor of which any man may well be proud; it is also a responsibility and, at the present moment, I am more impressed by this phase of the situation.

In the Boston Society of Civil Engineers there is a requirement that the President shall deliver an address at the close of his administration and, personally, I think this a very good rule. It is a much safer course to follow — at least from the standpoint of the President. At the end of his term he is probably a much wiser man than when he comes into office and he can then state what should be done and leave it to his successor to do.

There is no question but that there is much work to be done in this Association, if we are to hold our place in the water works field. We reached the high point in membership in 1917 with 950. That was a climb of some 250 members in the preceding three years. We are now down to 750, or in other words, we have lost 200 members in the last five years. From the 1921 list it appears that only 110 cities and towns in Massachusetts are represented in this Association, while there are in the State somewhat more than 200 water works. Only 200 men are listed in our total membership as superintendents or foremen and this number includes, in many instances, more than one member from the same city or town. Probably not more than one-third of the superintendents of water systems in Massachusetts are members of this Association, and right here is the weak point in our appeal to the public officials and to the public.

Roughly classifying the membership — sixty per cent are listed as engineers; twenty five per cent as superintendents and foremen, and the remainder as commissioners and miscellaneous. Including the engineers who are in charge of particular works, about fifty per cent of the members are engaged in the actual operation of water systems.

The point to be noted is the small percentage of superintendents and, in my judgment, this condition demands serious consideration. If we had completely sold the value of this Association to the public, it would not be possible for a man to become a superintendent in New England without first qualifying as a member of this Association. This brings up the questions of Corporate membership — such as is found in the American Water Works Association — and the possibility of convincing more public authorities that the expenses of the superintendent, in attending our meetings, should be paid.

There can be no question but that we should be able to maintain 1200 — 1500 members, without including any floaters who are drawn in as the result of some special drive and then later drift away. With a larger membership a much better Journal can be furnished and with a

better Journal we will more surely hold our membership, because the Journal is the greatest single factor in determining the future growth and welfare of this Association. Twenty per cent of our membership live beyond 500 miles; fifty per cent live beyond 100 miles and less than one-third live within 50 miles of Boston. To probably three-quarters of our members the Journal is the only return for their investment. Further, the preceding figures illustrate the fact that we are not a local organization; our membership is national and international, and our program should be planned accordingly. We should keep step with all processes and improvements in water treatment, without regard to their particular value under New England conditions, and we should coöperate with the American Water Works Association in their work of standarization.

Just a word to reinforce what the editor has said in reference to use of the advertisements in the Journal by the members. In my judgment, every man here, when ordering any materials, should refer to our Journal, and in his correspondence with advertisers he should make known this reference to the Journal. If the manufacturers can be shown that there is a direct response to their investment in our publication, a greater income from advertising will be obtained, and with increased income a better Journal can be provided.

I think I have said enough; I thank you. (Applause,)

Address by the President.

Mr. Sherman. For the address expected of the retiring President I have prepared to give you something a little in the nature of a technical paper rather than much comment upon the Association, although I would like to preface my paper by some few remarks, as probably should always be the case with a retiring President.

It is very easy for a man in laying down his position to look back and think over the things he ought to have done, and has not. There is an immense amount of work that a President of this Association can do, and perhaps I should say ought to do, and I am probably safe in saying that most, if not all, of my predecessors at the end of their terms have had much the same feeling that I have, which is that we have not begun to accomplish a tithe of what we ought to have done.

During the year the first consideration, the one that comes quickest to mind, is of course the change in membership, and it is somewhat disappointing, although not altogether surprising, if we realize, as we do from the Secretary's report, a net loss of 44 members in the year, in view of the increase in membership dues by fifty per cent which took effect in the year 1921, and I am inclined to think on the whole that is rather a less loss than we might naturally have expected, and that while it is disappointing it is not nearly as bad as it might have been.

Nineteen hundred and twenty-one marks the first year of the Association when we have attempted to govern its finances by a budget adopted in advance. The budget, including a recommendation for increased dues, was adopted late in 1920, and became applicable for the year 1921. For the first year I think the Association has been remarkably successful in that its total expenditures have very closely coincided with and been slightly under the amount allowed by the budget. Only two slight modifications of the amounts were found necessary. In two items the expenditures slightly exceeded the amounts estimated at the beginning of the year

The budget laid out for the new year, as Mr. Barbour has told you, includes a proposition to spend more money on the Journal than has been thought possible during the year past. The Journal, of course, is the most important single thing that the Association has. It is always a source of regret to do anything which cuts down the value of the Journal, and yet with the financial condition with which we were faced, especially with the extremely high cost of printing work of all kinds, it was absolutely necessary during the past year to economize radically in that direction. It has been done, and successfully done, but with the disappointment that we have not given you in print all we would have liked to do. Another year Mr. Barbour's administration will be able to do better, and we hope that each succeeding year will show greater improvement in the Journal.

Our losses in membership have been particularly marked. Among our honorary members we have lost by death four out of fourteen. The deaths of the honorary members were: Hiram F. Mills, William T. Sedgwick, George A. Stacy and Fred W. Shepperd, — two of them past presidents of the Association.

We have had during the year the most unusual experience of a bequest, one of our honorary members — Hiram F. Mills — having left in his will the sum of $1000 to the Association. The bequest has not as yet become available, but presumably will sometime during the coming year.

(Mr. Sherman then read a paper entitled "Some Observations of Water Consumption.")

Mr. George A. Carpenter.* Mr. President, there is one matter that I would like to bring to the attention of the Association before we adjourn. As I have listened to the report of the Tellers of the election I wondered if we were not allowing to pass by us without due recognition a fact of which we ought to take notice. When a member of this Asso ciation completes a long period of faithful service I think some notice should be taken of it. Today marks the close, if I am correctly informed, of nearly a quarter of a century of active, faithful service by one of our older members. I allude to Treasurer Bancroft, — one of the men who

*City Engineer, Pawtucket, R. I.

has always been present at the meetings, who has been faithful and conscientious in the performance of his duties to this Association over a long period of years.

Mr. President, I would like to move a rising vote of thanks in recognition and appreciation of that term of faithful service by our Treasurer.

(The motion was immediately seconded by a number of the members, and the entire company stood amid applause and cries of "Speech.")

THE PRESIDENT. Mr. Bancroft, you are officially thanked.

REMARKS BY MR. LEWIS M. BANCROFT.

MR. BANCROFT. Mr. President, and members of the New England Water Works Association: It is true I have served you to the best of my ability for twenty-three years as Treasurer, but it has been with great pleasure that I have filled that office. I somewhat regret that it is necessary for me to retire at the present time; it is of my own election. I feel it is for the benefit of the Association that I should retire at this time, because I expect to be away considerable of the time, and the Treasurer or any other officer of the Association should be where he can attend to his duties. I sincerely thank you for your appreciation of my services. [*Applause.*]

THE PRESIDENT. If there is no further business the meeting now stands adjourned.

(*Adjourned.*)

Remarks by President elect F. A. Barbour

Mr. Barbour. Mr. President and fellow members, I sincerely thank you for my election. It is an honor of which any man may well be proud; it is also a responsibility and, at the present moment, I am more impressed by this phase of the situation.

In the Boston Society of Civil Engineers there is a requirement that the President shall deliver an address at the close of his administration and, personally, I think this a very good rule. It is a much safer course to follow — at least from the standpoint of the President. At the end of his term he is probably a much wiser man than when he comes into office and he can then state what should be done and leave it to his successor to do.

There is no question but that there is much work to be done in this Association, if we are to hold our place in the water works field. We reached the high point in membership in 1917 with 950. That was a climb of some 250 members in the preceding three years. We are now down to 750, or in other words, we have lost 200 members in the last five years. From the 1921 list it appears that only 110 cities and towns in Massachusetts are represented in this Association, while there are in the State somewhat more than 200 water works. Only 200 men are listed in our total membership as superintendents or foremen and this number includes, in many instances, more than one member from the same city or town. Probably not more than one-third of the superintendents of water systems in Massachusetts are members of this Association, and right here is the weak point in our appeal to the public officials and to the public.

Roughly classifying the membership — sixty per cent are listed as engineers; twenty five per cent as superintendents and foremen, and the remainder as commissioners and miscellaneous. Including the engineers who are in charge of particular works, about fifty per cent of the members are engaged in the actual operation of water systems.

The point to be noted is the small percentage of superintendents and, in my judgment, this condition demands serious consideration. If we had completely sold the value of this Association to the public, it would not be possible for a man to become a superintendent in New England without first qualifying as a member of this Association. This brings up the questions of Corporate membership — such as is found in the American Water Works Association — and the possibility of convincing more public authorities that the expenses of the superintendent, in attending our meetings, should be paid.

There can be no question but that we should be able to maintain 1200 — 1500 members, without including any floaters who are drawn in as the result of some special drive and then later drift away. With a larger membership a much better Journal can be furnished and with a

better Journal we will more surely hold our membership, because the Journal is the greatest single factor in determining the future growth and welfare of this Association. Twenty per cent of our membership live beyond 500 miles; fifty per cent live beyond 100 miles and less than one-third live within 50 miles of Boston. To probably three-quarters of our members the Journal is the only return for their investment. Further, the preceding figures illustrate the fact that we are not a local organization; our membership is national and international, and our program should be planned accordingly. We should keep step with all processes and improvements in water treatment, without regard to their particular value under New England conditions, and we should coöperate with the American Water Works Association in their work of standarization.

Just a word to reinforce what the editor has said in reference to use of the advertisements in the Journal by the members. In my judgment, every man here, when ordering any materials, should refer to our Journal, and in his correspondence with advertisers he should make known this reference to the Journal. If the manufacturers can be shown that there is a direct response to their investment in our publication, a greater income from advertising will be obtained, and with increased income a better Journal can be provided.

I think I have said enough; I thank you. (Applause,)

Address by the President.

Mr. Sherman. For the address expected of the retiring President I have prepared to give you something a little in the nature of a technical paper rather than much comment upon the Association, although I would like to preface my paper by some few remarks, as probably should always be the case with a retiring President.

It is very easy for a man in laying down his position to look back and think over the things he ought to have done, and has not. There is an immense amount of work that a President of this Association can do, and perhaps I should say ought to do, and I am probably safe in saying that most, if not all, of my predecessors at the end of their terms have had much the same feeling that I have, which is that we have not begun to accomplish a tithe of what we ought to have done.

During the year the first consideration, the one that comes quickest to mind, is of course the change in membership, and it is somewhat disappointing, although not altogether surprising, if we realize, as we do from the Secretary's report, a net loss of 44 members in the year, in view of the increase in membership dues by fifty per cent which took effect in the year 1921, and I am inclined to think on the whole that is rather a less loss than we might naturally have expected, and that while it is disappointing it is not nearly as bad as it might have been.

Nineteen hundred and twenty-one marks the first year of the Association when we have attempted to govern its finances by a budget adopted in advance. The budget, including a recommendation for increased dues, was adopted late in 1920, and became applicable for the year 1921. For the first year I think the Association has been remarkably successful in that its total expenditures have very closely coincided with and been slightly under the amount allowed by the budget. Only two slight modifications of the amounts were found necessary. In two items the expenditures slightly exceeded the amounts estimated at the beginning of the year

The budget laid out for the new year, as Mr. Barbour has told you, includes a proposition to spend more money on the Journal than has been thought possible during the year past. The Journal, of course, is the most important single thing that the Association has. It is always a source of regret to do anything which cuts down the value of the Journal, and yet with the financial condition with which we were faced, especially with the extremely high cost of printing work of all kinds, it was absolutely necessary during the past year to economize radically in that direction. It has been done, and successfully done, but with the disappointment that we have not given you in print all we would have liked to do. Another year Mr. Barbour's administration will be able to do better, and we hope that each succeeding year will show greater improvement in the Journal.

Our losses in membership have been particularly marked. Among our honorary members we have lost by death four out of fourteen. The deaths of the honorary members were: Hiram F. Mills, William T. Sedgwick, George A. Stacy and Fred W. Shepperd, — two of them past presidents of the Association.

We have had during the year the most unusual experience of a bequest, one of our honorary members — Hiram F. Mills — having left in his will the sum of $1000 to the Association. The bequest has not as yet become available, but presumably will sometime during the coming year.

(Mr. Sherman then read a paper entitled "Some Observations of Water Consumption.")

Mr. George A. Carpenter.* Mr. President, there is one matter that I would like to bring to the attention of the Association before we adjourn. As I have listened to the report of the Tellers of the election I wondered if we were not allowing to pass by us without due recognition a fact of which we ought to take notice. When a member of this Association completes a long period of faithful service I think some notice should be taken of it. Today marks the close, if I am correctly informed, of nearly a quarter of a century of active, faithful service by one of our older members. I allude to Treasurer Bancroft, — one of the men who

*City Engineer, Pawtucket, R. I.

has always been present at the meetings, who has been faithful and conscientious in the performance of his duties to this Association over a long period of years.

Mr. President, I would like to move a rising vote of thanks in recognition and appreciation of that term of faithful service by our Treasurer.

(The motion was immediately seconded by a number of the members, and the entire company stood amid applause and cries of "Speech.")

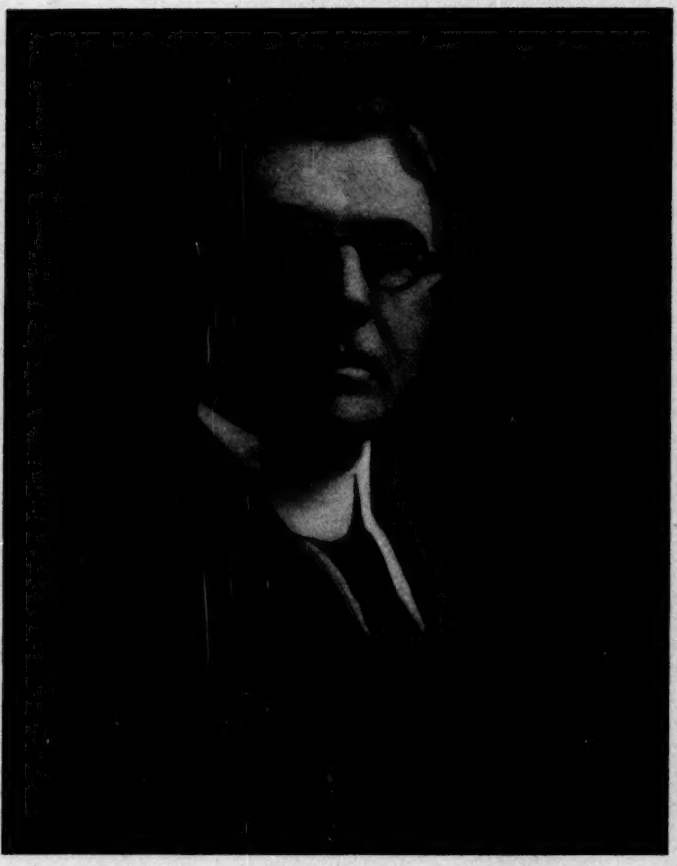
THE PRESIDENT. Mr. Bancroft, you are officially thanked.

REMARKS BY MR. LEWIS M. BANCROFT.

MR. BANCROFT. Mr. President, and members of the New England Water Works Association: It is true I have served you to the best of my ability for twenty-three years as Treasurer, but it has been with great pleasure that I have filled that office. I somewhat regret that it is necessary for me to retire at the present time; it is of my own election. I feel it is for the benefit of the Association that I should retire at this time, because I expect to be away considerable of the time, and the Treasurer or any other officer of the Association should be where he can attend to his duties. I sincerely thank you for your appreciation of my services. [*Applause.*]

THE PRESIDENT. If there is no further business the meeting now stands adjourned.

(*Adjourned.*)



FRANK A. BARBOUR,
President of the New England Water Works Association,
1922.